THE CANON FRONTIER 2017/2018

Focus on Technology and R&D

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About the Cover

A moonbow captured on a dark night. This phenomenon is so rare that it is said to bring good fortune to those who see one. The image was taken with a Canon multipurpose camera equipped with an ultra-high-sensitivity CMOS sensor.

Check!

Chapter 1

Inspiring Innovation

Innovations at Canon are grounded in the company's technology-focused DNA and the passion of its developers. Our innovations extend beyond cameras and office equipment to commercial printing, network cameras and even healthcare and industrial equipment.
We are constantly venturing into developing fields and seeking new challenges. By sharing our discoveries, we firmly believe we can uphold our philosophy of "Kyosei"—all people, regardless of race, religion or culture, harmoniously living and working together into the future—and contribute to a rich society.

Special Feature / Canon's Material Appearance Acquisition and Printing Technologies

Touching

the Frontier of Technical Development

Canon is working to develop technologies that reproduce not only color but also elevation and gloss from the original. Freelance announcer Hitomi Sano reports from the front line.

A reproduction of Johannes Vermeer's "Girl with a Pearl Earring" kept at The Royal Picture Gallery Mauritshuis (The Netherlands)

Satoru Torii

Joined Canon in 2004.

Field of study at university:
Medical image processing

Current position:
Image processing (input)

Chika Inoshita

Joined Canon in 2015.

Field of study at university:
Computer science

Current position:
Image processing
(analysis of reflectance properties)

Atsushi Totsuka

Joined Canon in 2009.

Field of study at university:
Computer science

Current position:
Image processing (printing)

Hitomi Sano

Freelance announcer

Joined NHK JOHO NETWORK, Inc. in 2001. Worked at NHK Niigata Broadcasting Station before turning freelance. Works on the "great gear" show (NHK WORLD TV), Tokyo Metropolitan Assembly live broadcasts (TOKYO MX TV) and more.


Three young engineers with Ms. Sano (left) by a reproduction of the "Girl with a Pearl Earring" (from left to right: Satoru Torii, Chika Inoshita, Atsushi Totsuka)

"Wow! Is it really okay to touch this?" exclaimed Hitomi Sano, extending her hand towards Dutch Master Johannes Vermeer's masterpiece, "Girl with a Pearl Earring." Of course you are not allowed to touch the original, as the painting is closely guarded at The Royal Picture Gallery Mauritshuis in the Netherlands, but thanks to Canon's material appearance acquisition and printing technologies, which are currently under development, you can get up close and personal with an identical reproduction. This one is not behind glass. You can see it with your own eyes and, yes, even reach out and touch it. Not only has the image been faithfully re-created, but also the brushstrokes on the canvas, the buildup of paint, the gloss of the finishing varnish, and even the cracks in the surface from 350 years of aging. The texture feels exactly like that of the original.

"'Girl with a Pearl Earring' has distinctive colors, such as these blues, yellows, and flesh tones. Looking at the reproduction you get the sense that the colors were reproduced not just by mixing colors together but by layering individual colors. Even the gloss and cracking are faithfully reproduced, making the replica virtually indistinguishable from the real painting. If you collected a number of these replicas, you could almost start your own art museum. The effect is totally different from ordinary photos or prints. When you have the texture of the original and can see and feel it, the emotional impact is completely different," says Sano.

Paintings are not the only target of Canon's material appearance acquisition and printing technologies. These technologies also allow the reproduction of textures ranging from fabrics such as velvet or denim to leather, rattan, gold leaf and many other materials. It is expected that such textures could be employed in building interiors and exteriors, product packaging, and many other areas. Let's take a closer look at the specifics involved in these material appearance acquisition and printing technologies.

Acquiring Color, Elevation and Gloss Information from High-Resolution Photos

Sano: Now I have looked at several reproductions of paintings, my honest impression is that I can't believe they have actually been printed. These are completely different from what people would consider ordinary prints. Can you tell me what kind of technology is used to make this possible?

Inoshita: Texture is both a visual and tactile element that people experience when looking at an object. Canon's material appearance acquisition and printing technologies are able to reproduce by working with the elevation and gloss characteristics in addition to the colors of an object. The processes involved are image capture, image processing and printing.

Sano: In that first step of capturing the image, do you use some kind of special camera?

Torii: We use a high-performance Canon digital SLR for image capture. For the Vermeer's painting we used multiple EOS 5Ds cameras. To acquire the color, elevation and gloss information we changed the position of the light source and cameras multiple times.

Sano: How do you acquire elevation data?

Torii: To capture elevation data, we project a striped pattern—essentially alternating areas of black, where light doesn't hit, and white, where light does—using a projector. If the surface of the object is smooth, the striped pattern is reflected in a straight line. If the object's surface is uneven, the striped pattern is reflected back with distortion. This distortion is captured by the camera and acquired as elevation data.

Sano: I see. That seems like an effective way to capture elevation data. Can you tell me how you acquire data on gloss?

Inoshita: Gloss is the sense of luster from an object. To estimate gloss, it is necessary


A Canon camera is used to capture images to acquire textural information

to measure the strength of the light reflected from the object and then digitize that value. By changing the position of the lighting and cameras, we can shoot photos while making fine adjustments to acquire data on at what angle and intensity the light is reflected from the object.

Torii: An important point that I should mention here is that these images are being captured at high resolution. In order to reproduce a texture that is identical to the original, you need data that is the same resolution as the human eyes. For that, we used the 50 megapixel EOS 5Ds and shot a postcard-sized area up close over and over, combining and processing those images so that in the end we had acquired elevation and gloss data at a resolution of several dozen micrometers*.

The Océ UV-curable printer currently under development

Estimating Surface Elevation and Gloss

Sano: So, you are able to acquire image data by photographing the painting to calculate the color, elevation and gloss. The next step is the image processing. What happens specifically in that step?

Inoshita: When we process the images, we are able to estimate the elevation and gloss of the painting from the photos taken. Regarding elevation, the camera captures the distortion of the striped pattern, from which we calculate the degree of distortion, and are able to compute the height of elevation at specific points in the painting.

Similarly, for gloss, we extract the differences in reflectance that are produced from the different angles of viewing, and convert that data into quantifiable parameters, which are saved as the gloss data. Both the elevation and gloss data obtained through these methods are then used in the printing process.

The UV-Curable Printer: Producing Fine Elevation

Sano: The final step is the printing. Do you use a special type of printer?

Totsuka: For this reproduction we used a UV-curable printer developed by Océ—a Canon group company. This printer uses UV (ultraviolet) rays to cure the ink. A repeat process of layering ink and curing it forms the elevation.

Ms. Inoshita performs image processing

Sano: I see. So, you take the color, elevation and gloss data from the image processing step and output it through this UV-curable printer. Could you explain how that process works?

Totsuka: Reproducing texture in a printed image involves a process of converting the quantified color, elevation and gloss characteristics into print data.

Let's start with the colors. Ordinarily, when you shoot digital photos you obtain RGB image data, in which colors are expressed in combinations of red, green, and blue. A printer, meanwhile, expresses colors using four colors of ink—cyan, magenta, yellow, and black, known as CMYK. Essentially, a conversion from RGB to CMYK must be performed. Canon had already developed proprietary color matching technologies for photo printing, those are what we use.

As I explained earlier, we print layer after layer of UV-curable ink to create the elevation. Basically, the height of the relief is controlled by the volume of ink used. The correlation between height and ink volume has been put into a database, which can then be referenced to reproduce the elevation.

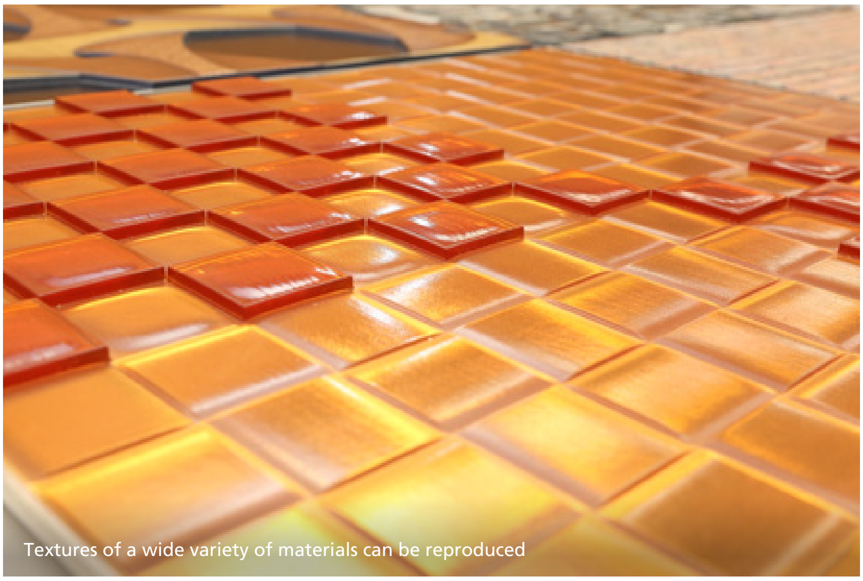
The third area involved in printing is the gloss. Gloss varies according to the smoothness of the surface of the object. For instance, the surface of glossy metal is extremely smooth, so it has high gloss, while fabrics have rough surfaces, and therefore less glossy. It is therefore possible to control gloss by controlling the smoothness of the print surface. We have developed such a method, which involves changing the smoothness of the print surface by

Ms. Sano is amazed by the faithful reproduction of the elevation, gloss and colors

adjusting how the ink is applied. Because we need to control fine elevation to the degree of several micrometers, a level invisible to the human eye, the control process needs to take into consideration not only the volume of ink but its placement and how the inks are layered.

Sano: It seems like there is quite a high degree of difficulty involved. Is gloss the key advance of Canon's material appearance acquisition and printing technologies?

Torii: You could certainly say that going beyond the reproduction of color and elevation to gloss is a major element of Canon's material appearance acquisition and printing technologies. Another of Canon's strengths is that it owns technologies and manufactures devices that cover input to output—both high-performance cameras and printers.



Textures of a wide variety of materials can be reproduced

Sano: I see. That is indeed one of Canon's strong points. Lastly, can you tell me how it felt to be involved in the development of this technology?

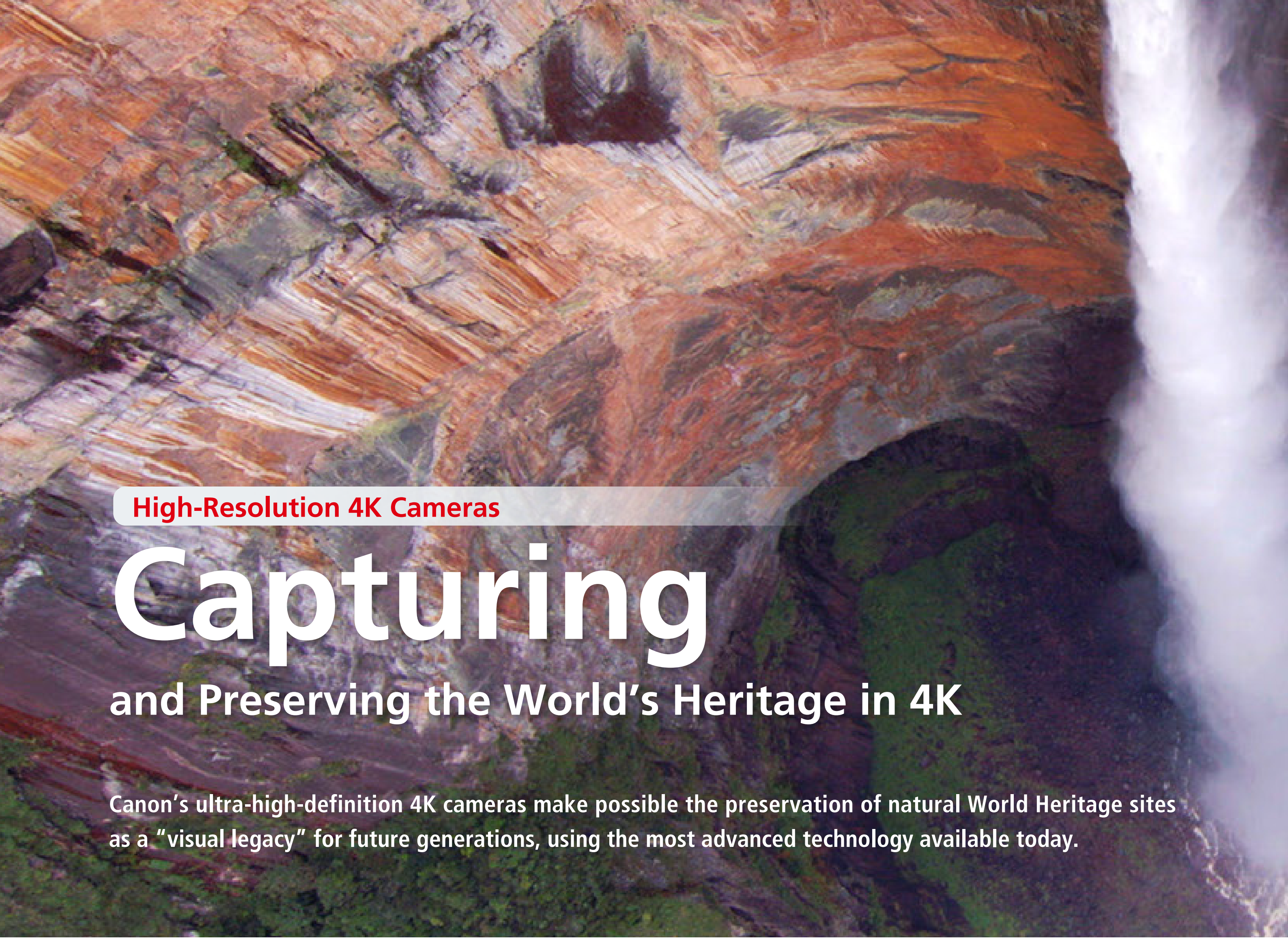
Torii: Canon's material appearance acquisition and printing technologies have achieved things that could not even be imagined a short time ago. By creating this kind of new technology, I hope we are able to enrich the lives of our customers. That is what truly makes my job feel worthwhile.

Inoshita: When I was a student, I saw examples of computer graphics used to reproduce texture. By the time I joined Canon, that had become possible with printing as well. Today, we can reproduce texture for flat objects, so what I would like to do in the future is try it with three-dimensional objects.

Totsuka: I think many people who have seen what 3D printers can do feel that the limitations of the printer as we know it are being redefined as we speak. Canon's material appearance acquisition and printing technologies present new possibilities for printing. Once people see what these technologies can do, they will have high hopes for the future of printing.

* micrometer (μm)= one millionth of a meter

Scan to access a special video and learn more about Canon's material appearance acquisition and printing technologies.



High-Resolution 4K Cameras

Capturing

and Preserving the World’s Heritage in 4K

Canon’s ultra-high-definition 4K cameras make possible the preservation of natural World Heritage sites as a “visual legacy” for future generations, using the most advanced technology available today.

A recording system that achieves high dynamic range and a high-performance fixed focal length lens are employed to achieve ultra-high-definition 4K images

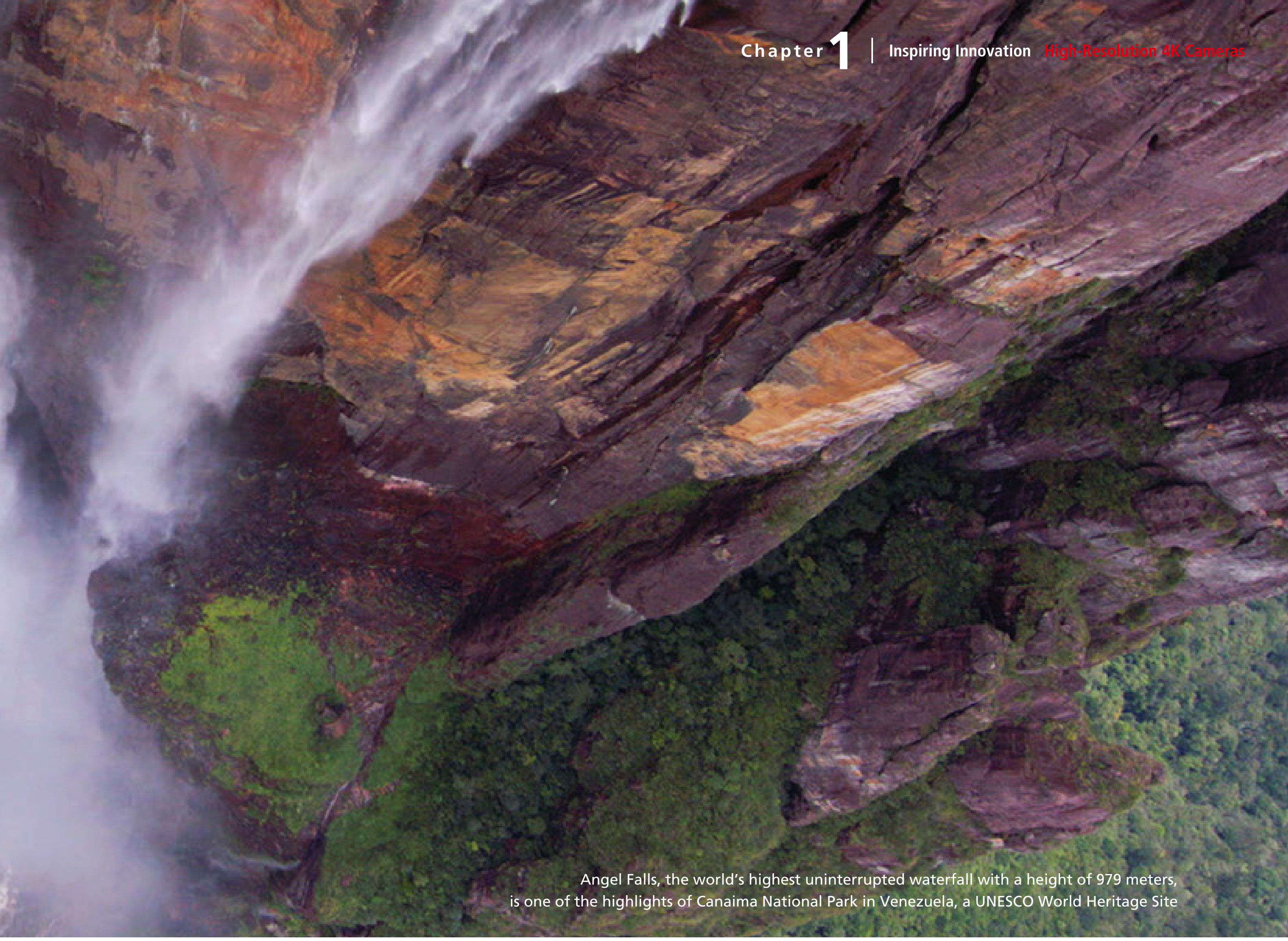
A EOS C300 Mark II camera is attached to a helicopter to take aerial shots of Angel Falls

The World’s Last Secluded Regions Recorded in Ultra-High-Definition Video

“The World Heritage” is a popular television program produced by TBS (Tokyo Broadcasting System Television, Inc.) that has shown over 600 world heritage sites over its 20 year run. Describing these efforts, the program’s 4K producer Naohiko Ogawa says, “We want to preserve for future generations a ‘visual legacy’ of the most precious World Heritage sites. Moreover, we want to record them in the best possible conditions, with the best equipment available. That has always been our approach, and every time new technology has come out, we’ve adopted it and put it to work.”

Canaima National Park in Venezuela is one of these magnificent locations. “The World Heritage” covered this site in 1999 and 2010, but the best technology available at the time was a high-definition camera. The program’s staff was eager to preserve this, one of the last of the world’s secluded regions, in 4K, so a team set out to film it a third time by living in tents as they climbed to the top of Auyán-tepui, “the devil’s mountain.” One of their targets was the world’s highest waterfall, Angel Falls.

To capture the full power of the waterfall on film, they set out during the wet season, when the volume of water would be the highest. However, filming would prove to be treacherous. “The last time we filmed, we climbed to the top of the tepui (tabletop mountain) and were caught in a fierce storm. In the middle of the night there was a huge downpour with gusting winds. Lightning seemed to strike right beside us, and one tent was even blown away. All we could do was pray for survival. I had never had such an experience



Angel Falls, the world's highest uninterrupted waterfall with a height of 979 meters, is one of the highlights of Canaima National Park in Venezuela, a UNESCO World Heritage Site

in my entire life." said 4K videographer, Nobuo Yaguchi.

When heading into such a harsh environment, it is necessary to trim the weight of equipment being carried in. The team had to forgo large displays and vibration control equipment. Seeking the lightest possible equipment, they decided on the EOS C300 Mark II and EOS-1D X Mark II, 4K cameras developed using leading-edge Canon technology. These cameras guaranteed high performance and high functionality while being compact and lightweight.

Canon's 4K Cameras Record the Invisible

"The most impressive thing to me about filming in 4K is that you wind up capturing things that you don't even see. Things that you couldn't catch with your naked eye are filmed and clearly visible when you see the footage later on your screen." says Mr. Yaguchi.

However, this impressive technology isn't found on just any 4K camera you might use. With some cameras, if you try to prevent overexposure of bright areas, you risk underexposure in dark areas. Likewise, if you adjust the exposure to capture the dark areas, bright areas become overexposed. With Canon's 4K cameras, that problem simply does not arise. This is made possible by Canon's proprietary Canon Log gamma setting, which can capture video with a high dynamic range equivalent to that of film, and with editing (grading), even details that couldn't be seen can be properly preserved in the footage.

One other feature that helped get the job done in this harsh environment was Canon's original autofocus feature, Dual Pixel CMOS AF. "Focusing is extremely important when filming in ultra-high-resolution 4K. The problem is that because of this high image quality, the human hand is not fast enough to adjust the focus on fast-moving objects. We were also constrained by not being able to use a large monitor, so our lifelines for video shooting were the image-sensor-based autofocus and object tracking capabilities," says Mr. Yaguchi.

The footage shot by the production team was broadcast in June 2016. Although the episode was converted to Full HD (high definition) when it was broadcast because terrestrial digital broadcasting in Japan does not yet support 4K, the overwhelming beauty of the images drew a huge response after the program aired. 4K BS broadcasting is scheduled to begin in 2018, at which time we look forward to seeing an even higher image quality broadcast on "The World Heritage."

Naohiko Ogawa (left)

Deputy GM,
Media Business Unit, TBS Vision
Executive Producer (4K producer)

Nobuo Yaguchi (right)

President, Heat One Inc.
(4K videographer)

世界遺産 THE WORLD HERITAGE

TBS's "The World Heritage"
Broadcast on TBS every Sunday
at 6:00 p.m. (Japan)

Special Interview

AI Phase Shift: Tectonic Change Spells for Manufacturing Firms

Today there is no technological term that promises greater expectations than Artificial Intelligence (AI). The use of AI has the potential to build a future beyond our wildest imagination. When it comes to this field, however, Japanese firms were slow off the mark. Will they be able to catch up? We talked about the future of AI with Mr. Junichi Tsujii, Director of the Artificial Intelligence Research Center of the National Institute of Advanced Industrial Science and Technology (AIST), and Mr. Yasuhiro Tani, Canon Inc. Senior Managing Executive Officer and Digital System Technology Development Headquarters Group Executive.

Yasuhiro Tani
Digital System Technology Development Headquarters Group Executive and Canon Inc. Senior Managing Executive Officer

Joined Canon in 1980. Appointed in 1994 to post at FirePower Systems, Inc. of the U.S. Became head of the SOC Design Center in 2003 and the SGM of platform development in 2007. In 2012 he became the Group Executive of Digital System Technology Development. Tani has long been involved in the development of digital products, including his time working in the United States.

Can you please explain AI (Artificial Intelligence) in simple terms?

Tsujii: Today, AI is a term used in many different fields, so its definition has broadened quite a bit. But simply put, it means "to autonomously think, make judgement and take action."

When was AI first developed?

Tsujii: Around the middle of the 20th century. Modern computers were just around the corner, and along came an idea that human intelligence is based on computation. Alan Turing—known as the father of artificial intelligence—among others supposed that if human intelligence was a matter of processing information, then a machine could simulate any process of formal reasoning; the debate took off from there.

What they didn't think very deeply about at the time was what exactly constituted human intelligence. Much later, as use of the term "AI" spread rapidly, research fields focusing on AI became established.

What kind of methods were being used to research artificial intelligence?

Tsujii: AI researchers had defined intelligence as a type of computation, but initially they did not know specifically what to research. So they set out to develop computational programs to tackle things considered to be human intelligence problems. Recent salient examples are computers playing (and beating human champions in) the games of Go and Shogi.

So basically, because intelligence is not easily definable, researchers first based their model on human beings. They converted behavior considered to be intelligence-based into computations, and processed them using computers. To do that you needed programs. So essentially, AI research was the pursuit of program development.

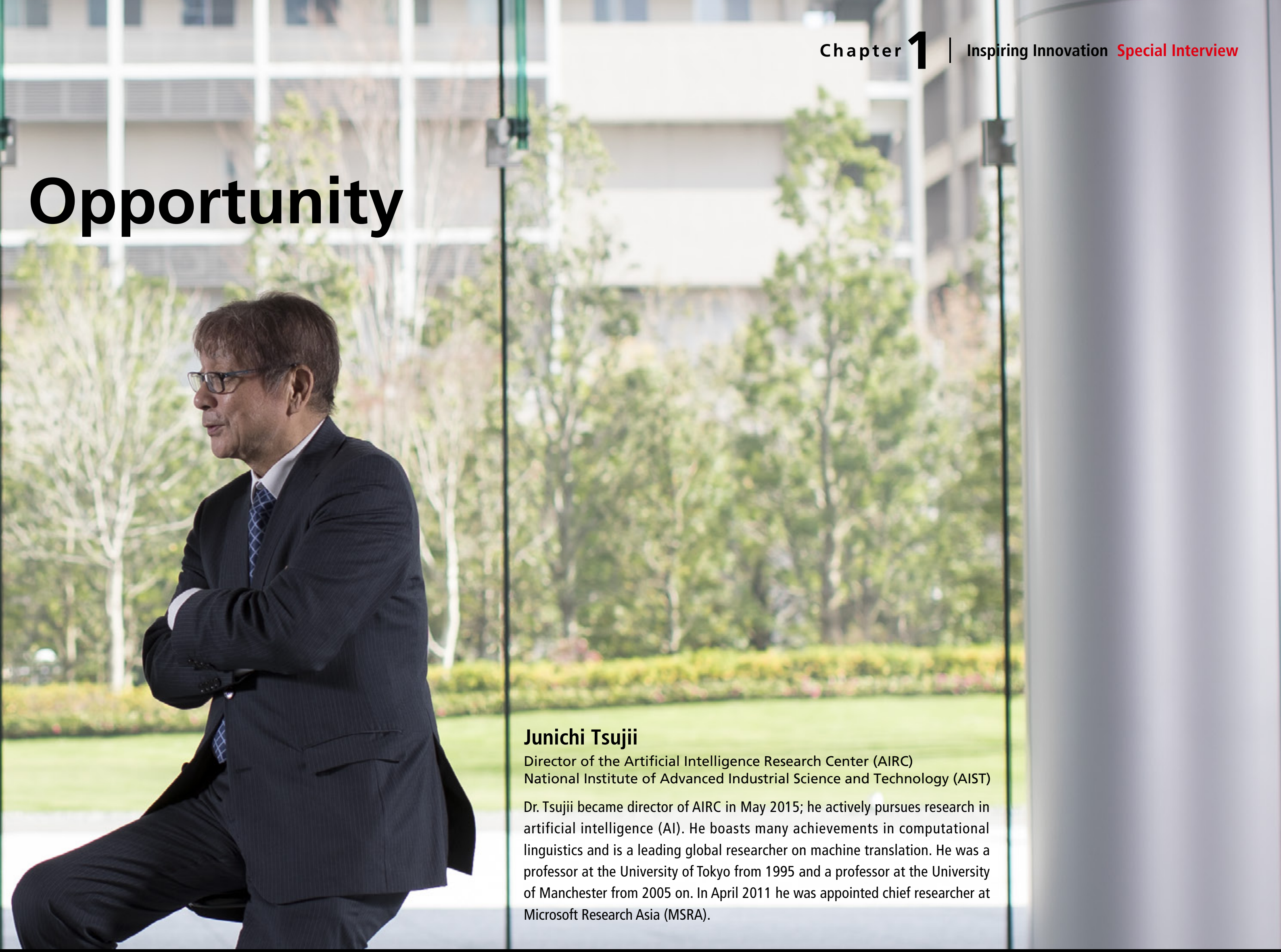
It seems that recently interest in AI has skyrocketed all at once. What do you think has prompted this?

Tsujii: The reason for the sudden interest is big data. With advances in the Internet of Things (IoT) in particular, we have entered an age in which huge volumes of data can easily be input into computer systems. That data is analyzed and regularities buried in the data are extracted, enabling situational judgement to be made and actions taken.

Take the diagnosis and treatment of an illness, for instance. If you acquire data from large numbers of patients and accumulate that data, when new patients arrive at the hospital you will be able to diagnose what kind of illness they have based on the results of analyzing all of that amassed data. Regarding treatment, if you store up knowledge from previous treatments as data, then you will know in advance that a certain treatment has been very effective for a certain type of patient.

This is hugely significant progress because you are able to link judgement to action. Computers do not merely offer a diagnosis. They find an effective treatment depending on the type of patient. That is a form of judgement that leads to the subsequent action of treatment. To put that another way, the computer determines what action should be taken when faced

Opportunity



Junichi Tsujii
Director of the Artificial Intelligence Research Center (AIRC)
National Institute of Advanced Industrial Science and Technology (AIST)

Dr. Tsujii became director of AIRC in May 2015; he actively pursues research in artificial intelligence (AI). He boasts many achievements in computational linguistics and is a leading global researcher on machine translation. He was a professor at the University of Tokyo from 1995 and a professor at the University of Manchester from 2005 on. In April 2011 he was appointed chief researcher at Microsoft Research Asia (MSRA).

with the situation of new patients at a hospital. This process is the same as the computer having intelligence, and is the very definition of AI.

Why did big data trigger this change in AI?

Tsujii: AI research up to that point had been based on the human model and was aimed at simulating human reasoning. But once big data was brought into the equation, there was an acceptance that judgement and action need not be based on the human model.

For instance, there is the process of looking for regularities in data accumulated from treatment results for a large number of patients. People are not good at this task but machines are. By delegating the responsibility to computers, the possibility emerged that perhaps computers could reach judgement and deduce actions using methods that differed from the way people think. We could use the assistance in areas that humans have trouble with and could especially use the results. So, particularly in the area of judgement, this development triggered an "AI boom."

Bringing Imaging into the Picture for AI Applications

How does Canon define AI?

Tani: In the second AI boom of the 1980s, Canon even released a Palmtop computer called the AI Note. But Canon did not have a clear definition of AI at that time. Several years earlier, a vision was outlined at Canon and technology development began with a focus on the fusion of the real (devices) and the cyber (information and communications technology—ICT) to generate sprouts of new businesses.

Canon is an imaging company. It has built its business upon imaging as its core strength. Cameras, printers, copiers, medical devices, and most other products made by Canon involve working with visual data. The company's vision involved connecting this wide range of equipment that spans input to output with cyberspace, thereby generating new value. So, you have a camera or other input devices that collect visual data, then through cyberspace you accumulate and analyze data, gather the meaning from it, make judgement, and using a printer, copier or other information device feed that information back into the system. The technology to realize this company vision was named Advanced IRT (Advanced Information & Real-world Technology).

All around us now, a third-generation AI boom is occurring. After close analysis, we realized that our R&D concept of Advanced IRT matches this new trend in AI. We came to the conclusion that the development of combining information technologies with the real-world technologies, it is the best way for Canon to pursue AI research.

What is Canon's biggest goal in pursuing AI?

Tani: Up to this point, Canon's business has been predicated on increasing image quality in the individual pieces of equipment we make and sell. From this point forward, we are aiming to incorporate AI into image-quality-enhancing technologies

"In the AI shift from cyberspace to the real world, Japanese firms will rebound."

to both strengthen our equipment business and expand into new systems and solutions—moving from products into solutions, if you will. We also envision the capabilities of AI having such applications not only in the business sphere but also in our manufacturing, in procurement, quality and IT infrastructure.

Do video and still images have an important role to play for AI?

Tani: There is a particular affinity between image recognition and AI. Canon possesses facial recognition and other image recognition technologies, and maintains strong competitiveness in this field. Of course there are some areas in which American IT firms have much more advanced image recognition technologies, and other areas Canon is more advanced. I want to see the company take full advantage of those strengths. Earlier it was mentioned that one reason for the spread of AI was the rapid evolution of IoT technologies. In the five-year mid-term plan for the Canon group launched in 2015, Canon Chairman & CEO Fujio Mitarai proposed that the IoT age will be a tremendous opportunity for Canon if we consider the "I" in IoT to be "Imaging," as we possess many technologies that are needed for both collecting and outputting still and video image data, such as lenses, sensors, and processors. From that point on, we began to think of the "Imaging of Things" as an additional definition of IoT to guide our technical development efforts.

What results have already been achieved through AI research?

Tani: The first thing we worked to develop were recognition technologies, ideally to be applied in the area of manufacturing, which Canon excels in, so we chose to research the "eyes" of robots.

The human eye and the "eyes" of robots seem the same but are different. Robots can utilize computer data, so image data captured by the eye can be matched with CAD data. Human beings also do this matching in our heads quite naturally, but we lack the precision of robots, which are better at the task. Utilizing this technology, we have already commercialized 3D machine vision system that can identify parts for robots to pick up by referencing CAD data.

A Phase Shift in AI Presents an Opportunity for Japanese Firms

What effect will the proliferation of AI have on Japanese firms as we look ahead?

Tsujii: A phase shift is now taking place in AI technology. Up to this point, American IT firms have been ahead of everyone else in research, with cyberspace as the main battlefield. These firms were good at gathering data from cyberspace.

But more recently, large volumes of data are not only being acquired from cyberspace, but also from the real world. This is the phase shift. In the new phase, it is not a strong advantage to the major firms with cyberspace expertise. Canon and other manufacturing companies are likely to become key players in AI.

A clear example is self-driving vehicles. The self-driving vehicle relies on data from the real world, not cyberspace. For this reason, American IT firms should be thinking of diversifying from cyberspace into the real world. Japanese firms have a strong grounding in real-world fields, so they are trying to work out how best to move from the real world into cyberspace. Taking this into consideration, Japanese firms have the potential to build out AI in ways that differ from the American model.

Why do American companies have the lead in AI development?

Tsujii: To find the answer you need to consider three components that support AI technology.

The first is big data, and the second, computational resources. You need to have the computational power to process the vast amount of data gathered from cyberspace. That requires large-scale data centers, and American IT firms have those facilities. The third is the business model—the path of how to make AI into business.

The major IT firms in the U.S. were able to put those three components together well, which led to their success. But as we have been saying, a phase shift is occurring in the world of AI. If vast amounts of data can be input from the real world, the gap between American IT firms and Japanese firms with regard to big data will eventually disappear.

What about computational resources?

Tsujii: Japanese companies are somewhat behind in computational resources. Japan does have supercomputer technology, with the likes of the K computer, but AI requires a data-oriented approach to process big data, as well as GPU-accelerated computing that relies on a graphics processing unit for machine learning. These realities are

driving computing to evolve in a different direction from the K computer.

You also have the business model. This holds the real key to success going forward. American IT firms and others have so far been providing AI-based recommendation functions. That means selecting the most apt information to supply on the basis of input keywords, utilizing the corpus of data they have to the greatest effect. This function is an excellent match for their business model.

However, with applications for AI expanding, new questions emerge, such as what kind of AI technologies are best suited to the manufacturing industry and how can AI be applied to drug discovery and medical treatment? These types of business solutions are not an especially good match with the strengths and business model of American IT firms. Japanese firms have a good chance to be competitive in this area.

Tani: In this regard, Canon is also considering utilizing cameras in the business-to-business (B2B) market. Business customers face a wide range of issues, and as just discussed, we think that AI can be used as a means of resolving those issues.

Canon would then be able to offer camera systems and services that extend beyond the performance of the cameras themselves to include advanced image processing and recognition functions enabled by AI. Nobody is willing to pay for the maintenance of cameras alone, but if we offered high-level camera systems and services to meet customers' individual needs, we could have a business model that would include revenue from maintenance.

To what degree does AI enhance Japan's manufacturing capabilities?

Tani: The ultimate form of manufacturing is to have robots perform all assembly operations, moreover, in small-lot, multi-variety, without human beings in the picture at all. People are working to develop the structure of such systems. Once that is accomplished, I believe that Japan as a manufacturing-oriented nation will find itself in a strong position again.

Many people are suspicious of this view of the future, however. In Japanese factories today, competitions are held to cultivate high-level individual skills in assembly, machining, and other areas; the competitions also serve a promotional function. So if robots take over all assembly tasks, people wonder, won't such skills become unnecessary in the future? Personally, I think that people will not lose the desire to push the limits of their skills. I also presume that the most efficient use of human labor would be in the initial stages prior to mass production. That is where high-level skills could be best utilized. Once production volumes increase, then the shift can be made to robots. If you have that kind of flow, I believe it can be the basis for a strong system of manufacturing.

Tsujii: I see it the same way. The research center adjacent to my own workplace is the Robotic Biology Institute, Inc., set up by a venture firm. It has developed a humanoid robot to conduct bioscience experiments. The premise had been that you needed people with high proficiency to perform certain tasks, but they have been able to transfer such high-level skills to a robot. As a result, the quality of the experiments rose and a large volume of data could be acquired. As we all know, when people perform a task, variations will inevitably arise. The experiments show there is a strong possibility that eventually even highly difficult tasks that we once thought could only be done by human beings will be transferrable to robots.

Yet, we should not lose sight of the fact that you still need people to model those high-level skills or it would be impossible to teach robots to perform those tasks. Say you are designing a new bioscience experiment. First you need a person to determine whether or not the experiment will work. Also, if a person can learn a skill, then it can be transferred to a robot for mass processing. When using AI to take manufacturing to the next level, you will always need people to step in and mediate the process if any progress is to be made. This is a very natural course of development, in my mind.

Tani: That is exactly right. Even in Canon's factories we have highly skilled workers and meisters—people whose job involves a high level of technical skill. When you involve such professionals in drafting improvement proposals, the technical level of those proposals jumps. Then if you use AI and robots in the phase of automation and labor reduction, even further advances can be made in manufacturing.

What other issues do Japanese companies face in using AI?

Tsujii: As we discussed earlier, AI will be incorporated into more comprehensive systems. It will require collaboration among people in different types of industries to build such a system overall. And to make that happen will require broad-based planning ability. The problem is that there aren't many Japanese people who are good at comprehensive planning. Working outside of a vertical organizational structure and connecting what you do to something completely different is not often done. So it will be necessary to cultivate talent that can create lateral connections, along with the ability to plan.

That means there needs to be human intelligence in order to utilize artificial intelligence.

Tsujii: Precisely. Japan's component technologies are at a very high level, but the ability to connect them to create something new is weak.

Tani: We also face that kind of problem. In cameras and MFPs we manufacture world-class products that are used across the globe, but we lack the imagination and planning capabilities to build systems that employ those products. Once we are able to break through and develop those abilities, Japan's manufacturing should become even stronger.

Commercial Printing

Changing
the Future of Printing

In commercial printing, offset printing has long been the primary means of producing such printed matter as posters, catalogs, books and newspapers. Today, digital printing is rapidly making inroads into this sector.

Leveraging the Merits of Digital Printing to Enter the Commercial Printing Market

Although commercial printing jobs can involve print runs ranging anywhere from tens of thousands of copies to several million, there is an increasing need for high-mix, low-volume printing. Additionally, printing paper has diversified to include glossy paper, pressure-bonded paper, carbonless paper and card stock. These realities of the commercial printing market today pose challenges for conventional offset printing.

That is why digital printing has been garnering increased attention. Digital printing, which enables printing directly from source data, offers such advantages as small-lot individualized print runs as well as variable-data printing, in which content can be changed from one page to the next. To meet demand in the growing digital printing market, Canon is working hard to improve quality, productivity and reliability.

An Extensive Lineup Spanning the Entire Commercial Printing Sector

Canon's strength lies in its ability to provide ideal products to satisfy individual customer objectives. The Canon Group, which includes Océ, boasts an impressive product portfolio, from continuous-feed and cut-sheet printing systems to large-format inkjet printers. A key advantage is that these products all share common operability and user interfaces, so they can be used with the same familiarity.

While Canon works to expand applications for its continuous-feed printing systems for large-volume print jobs, including high-speed printing, variable-data printing and printing on specialty paper, the company's cut-sheet printers for small-lot print runs offer the flexibility to handle everything from the printing of books and manuals to high-image-quality print jobs. With an emphasis on speed, image quality and durability, Canon offers a diverse product portfolio designed to meet the needs of any customer.

Looking to the future, Canon has set its sights on the industrial printing sector, aiming to expand the potential of digital printing by enabling printing and package printing on materials other than paper, such as ceramics and metals.

Collaboration with Océ

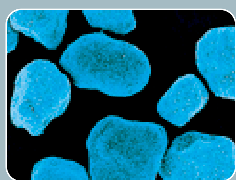
Océ, a company with a proud history spanning more than 130 years, joined the Canon Group in 2010. The competitive printers that Océ develops have garnered tremendous support within the market for their reliability and production capacity. Canon's collaboration with Océ, which boasts a strong presence in the high-end segment of the commercial printing industry in Europe, represents another step toward the realization of Canon's Three Regional Headquarters management system, which targets the promotion of innovation in the U.S. and Europe.

In addition, the Customer Experience Center Tokyo (CEC Tokyo) was opened in Shimo-maruko, Ota-ku, Tokyo, in April 2017. Customers can bring in their own data and paper to experience Océ products for themselves.

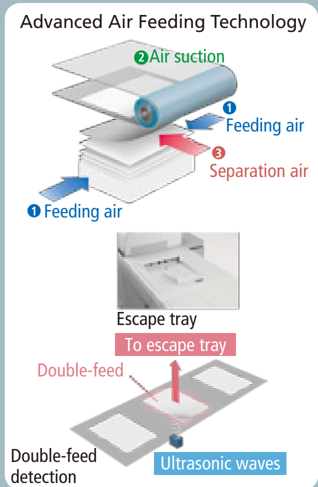

Trying out printing at CEC Tokyo


imagePRESS C10000VP

[High Quality]
Next-generation CV toner delivers excellent color reproduction through optimized fusing characteristics



[Stability]
Advanced Air Feeding Technology employs three air-powered operations: feeding air, air suction and separation air



[Controller]
PRISMAsync maximizes print engine performance
This high-functionality printer controller is equipped with print job management functionality. By predicting the duration of print jobs and the timing of paper refills and consumable replacements, it helps to minimize downtime.

[Productivity]
A Dual fixing system adjusts the paper path according to the quality of the paper

Network Cameras

Imaging Technology for Safety and Security

Network cameras are becoming standard equipment for disaster monitoring and crime prevention. There is also growing demand for their use in marketing and for raising productivity. In this favorable business climate, in addition to high-performance network cameras that making the best use of the Company's optical and image processing technologies, Canon is working hard to develop video content analysis software.

Image captured using the AXIS Q1659

Expanding Applications for Network Cameras on the Strength of High Image Quality

The utilization of network cameras is widely expanded to the various purposes by combining cloud services and image analysis. In addition to such core camera technologies as optics, CMOS sensors, imaging processors and image analysis software that the company has developed over the years, Canon is leveraging its strengths in the areas of network control and cloud services, areas the company has developed for its office equipment systems. The goal is to realize a solutions business that uses big data in imaging for more than just crime prevention and monitoring.

For instance, network cameras make it possible to analyze the flow of people for use in retail marketing, or to analyze the movement of workers in a factory or warehouse to assist in improving the configuration of a production line or placement of shelving.

Advanced image analysis draws out hidden value from images and holds great potential for network cameras in a wide range of industries including logistics, education, healthcare and nursing.

Combining Group Company Technologies Endeavoring to Become the Global Leader by Creating Innovative Products

As the market grows rapidly, Canon considers network cameras to be a highly promising new business sector. Capitalizing on this opportunity, Canon has welcomed Axis Communications (Sweden), which excels in network video processing technologies, and Milestone Systems (Denmark), known for its image processing software, into the Canon Group. To this mix Canon adds superior imaging technology to produce some of the industry's most innovative network camera systems.

VB-M50B

VB-S30VE

VB-H761LVE

AXIS Q1659 (shown with an EF85mm f/1.2L II USM lens)


Wide-angle monitoring in a city

The Fusion of Canon and Axis Technologies Produces High-Resolution Monitoring

The AXIS Q1659, which combines Canon's superior optical and imaging technologies with Axis' network image processing technology, marks Canon and Axis' first jointly-developed product.

This network camera features the same Canon-developed high-performance image sensor and image processing engine employed in the Company's EOS series of interchangeable-lens cameras. It supports high-resolution monitoring at approximately 20 megapixels and 8 frames per second (fps).

The AXIS Q1659 also allows the selection and use of seven EF-series interchangeable lenses, from wide-angle to telephoto for a variety of monitoring situations. This system, which combines the ultimate in Canon technologies, allows clear, high image quality capture for urban locations, airports and stadiums, where both wide-angle and telephoto lenses are needed.

Photoacoustic Tomography

New Advancements in Medical Technology

Cutting-edge laser light sources and ultrasonic sensors, combined with image processing technology, are giving birth to a new type of diagnostic imaging equipment for use in medicine.

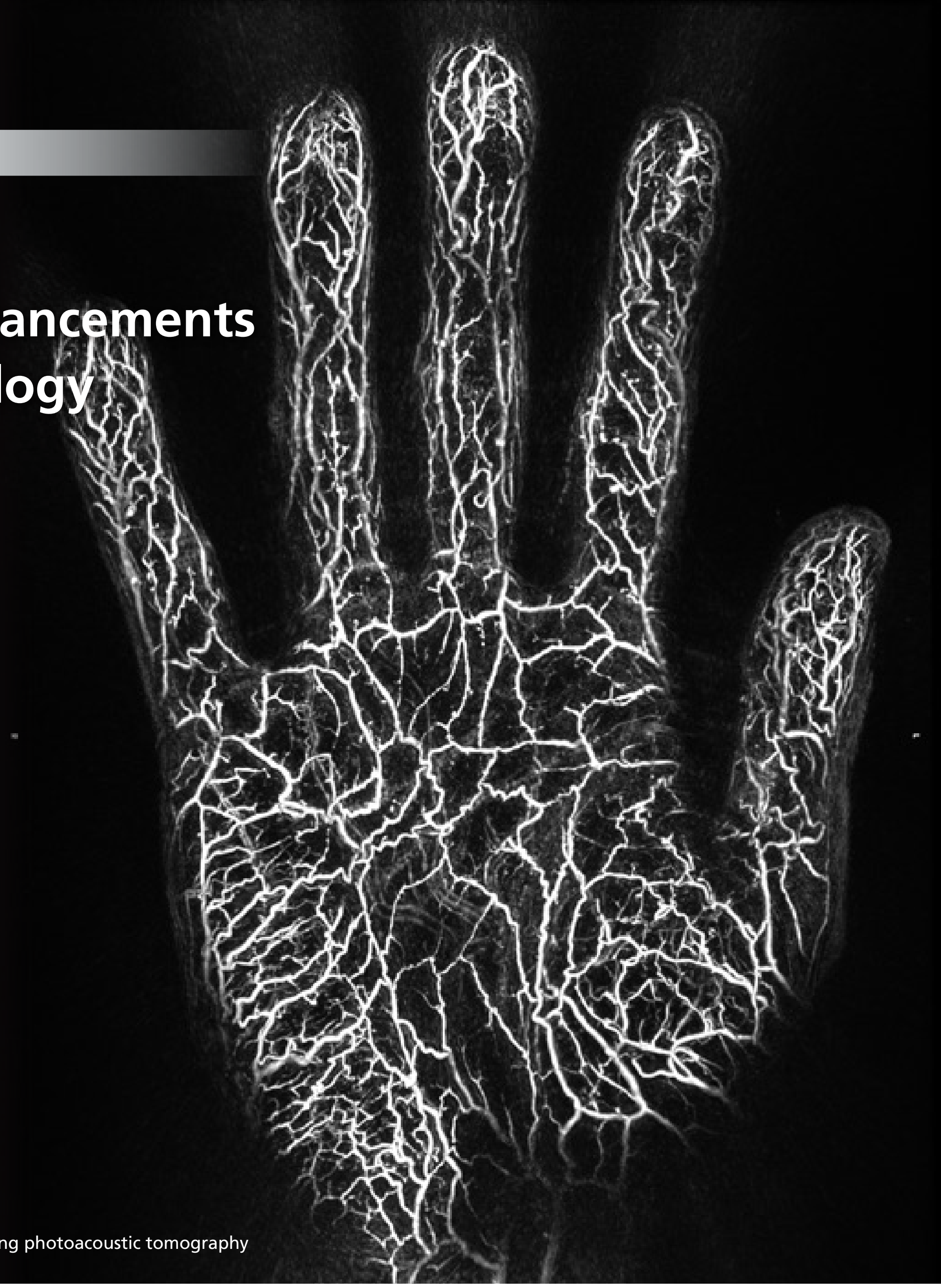


Image of blood vessels in the hand acquired in 3D using photoacoustic tomography

Photoacoustic Tomography

Non-invasive 3D Imaging of Blood Vessels with No Radiation Exposure

Blood vessels play the vital role of carrying oxygen and nutrients to the entire body. It is also said that the onset and progress of various diseases can be observed through changes in blood vessels. Visualizing blood vessels therefore has major medical significance. Up to this point, in order to visualize blood vessels, a CT (Computed Tomography) scanner or angiography system is used as modality (medical equipment used to take images).

When taking images using a CT scanner or angiography system, a contrast agent is injected into the blood vessels, and radiation (x-rays) is used to take images. However, such methods have risks to cause physical damages.

As a modality to solve these issues, photoacoustic tomography (PAT) is attracting attention. When an object absorbs light, the object thermally expands, and emits ultrasound. The basic idea of PAT is to detect this ultrasound, and visualize the object based on this ultrasound. When a near-infrared laser is used on a living subject, the hemoglobin in the blood vessels absorbs the light and emits ultrasonic waves. These ultrasonic waves are detected by ultrasound sensors, and the 3D image of the blood vessels in the subject is then visualized after reconstruction of the ultrasonic waves, PAT technology is non-invasive and radiation-free, so it is expected to apply to the diagnosis of several diseases such as cancer, diabetes mellitus, and rheumatism.

Diagnosis using PAT

The Technical Development of Devices and Systems to Support Photoacoustic Imaging

A PAT system consists of a laser light source, ultrasonic sensors, a reception module for converting the signals received from the ultrasonic sensors into digital data, an image reconstruction module for creating the image from the digital data, an operating/display module for displaying the images of the blood vessels, and so on.

Canon has developed state-of-the-art laser light sources, high-sensitivity ultrasound sensors, high speed 3D reconstruction algorithms for converting digital data, and high-resolution image processing technologies that increase the signal-to-noise ratio. Based on these technologies, Canon is developing pre-commercial systems to establish PAT as a new modality. One such system is the photoacoustic mammography system jointly developed with Kyoto University. Photoacoustic mammography aims to detect breast cancer earlier by visualizing the abnormal formation of new blood vessels.

Canon's PAT Technology Used in a National Project in Japan

Canon's PAT technology is being used in ImPACT (Impulsing PAradigm Change through disruptive Technologies) program being run by the Council for Science, Technology and Innovation of the Cabinet Office. The program manager is Takayuki Yagi who was involved in the development of photoacoustic mammography at Canon. Through the program, efforts are being made to visualize fine blood vessel network and blood condition in real time at higher resolutions. Canon's photoacoustic mammography is being used as the foundation for this research effort.

"In the ImPACT program we are working on the imaging of blood vessels in which abnormalities appear with illnesses such as cancer, arteriosclerosis diabetes mellitus and arthritic disorder. The key points are how to capture images of fine blood vessels and how fast that imaging can take place. If higher resolution than existing contrast imaging methods such as CT and MRI scans can be achieved, these diseases can be detected at an earlier stage and medical expenses can be reduced," says Mr. Yagi. MRI scans provide imaging of blood vessels at around 1mm in diameter, and CT scans at just under 1mm, with the use of a contrast medium. The goal of the PAT system under development at ImPACT is to make visible blood vessels that are 0.2mm in diameter and oxygen saturation without the use of a contrast medium.

In photoacoustic imaging, images are created by detecting weak acoustic waves and repeatedly accumulating them. A few years ago it required approximately two minutes to detect. Today it can shorten the time it takes to detect and image less than one second by the research effort.

In the ImPACT program, Canon is in charges of developing image reconstruction algorithms, optical system and mechanism and designing ultrasonic sensors. Mr. Yagi states, "Image reconstruction algorithms and sensor designing are the most important techniques that determine system resolution and imaging time, and are also the areas that require the most expertise. It is no exaggeration to say that Canon has world-leading technologies."

Takayuki Yagi

ImPACT Program Manager

Joined Canon in 1983. Appointed as ImPACT Program Manager in September 2014. Currently on assignment to ImPACT from Canon.

Synergy with Toshiba Medical Systems

In 2016 Toshiba Medical Systems Corporation (TMSC) was welcomed into the Canon Group. TMSC is a leading global company in the medical equipment industry with a core competence in diagnostic imaging systems such as CT, MRI and diagnostic ultrasound systems. Canon brings advanced production technologies to the table, including precision design and microfabrication technologies that will boost quality and price competitiveness and improve management efficiencies. Additionally, Canon's original high-speed x-ray imaging sensors and PAT technology, which was selected for the ImPACT national project, will be used to develop highly innovative next-generation medical equipment.

320-row area detector CT system

3 Tesla MRI system

Toshiba Medical Systems Corporation

Biomedical Solutions

Pioneering

Biomedical Technology

Canon is cooperating with research institutes in the U.S., a country at the forefront of modern medicine, and is applying its strengths in optical and imaging technologies to the biomedical field.

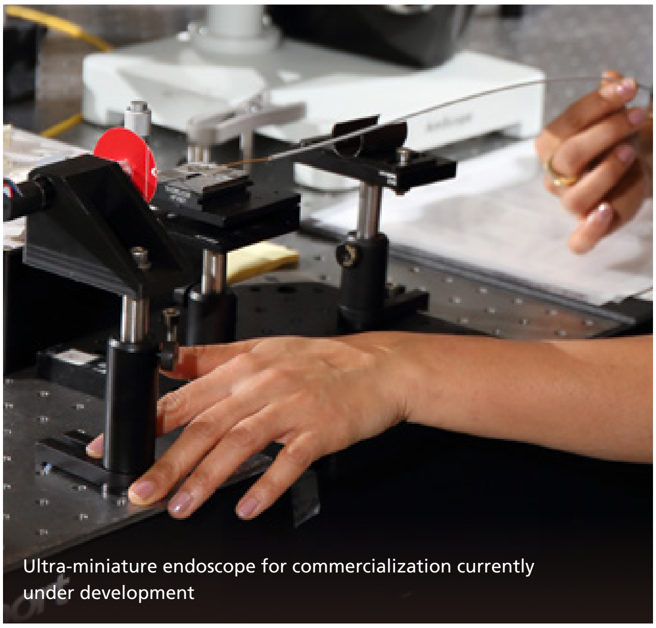
Genetic Testing Products

Testing Tough Genetic Targets with Simple Genotyping Solutions

Genetic testing makes it possible to identify individual susceptibilities to congenital disorders, the likelihood of contracting a disease, and potential side effects of medications. In the U.S., Canon is developing genetic testing products that can perform complex tests in less than an hour. Canon U.S.A. established Canon BioMedical, Inc. (CBMI) in March 2015, aiming to commercialize instruments and reagents that leverage core Canon technologies, such as CMOS sensors and inkjet printing technologies, to address the unmet needs of molecular geneticists. In September 2015, CBMI launched Novallele Genotyping Assays* and their associated reagents, that test for specific DNA sequences. Since then CBMI has launched over 350 unique assays that test for a range of genetic variations. These rapid tests amplify DNA, making it possible to detect these variations that impact human biology. The CBMI team continues to develop assays that target hard to detect genetic variations to help support genetic researchers.

At the Healthcare Optics Research Laboratory in Boston, Massachusetts, Canon is collaborating with Massachusetts General Hospital and Brigham and Women's Hospital, both teaching affiliates of Harvard Medical School, to develop and commercialize such products as state-of-the-art endoscopes and robotics-assisted medical devices that are more reliable than manual devices.

Genotyping assays under development at CBMI



Ultra-miniature endoscope for commercialization currently under development

Development of a prototype system comprised of image guided navigation software and robot

Ultra-Miniature Endoscope

Endoscope with Diameter Less Than 1mm to Open the Way for New Applications

Canon is leveraging technological strength in such areas as micro-optics fabrication technology, diffraction optics simulation, and optical design technology, to develop an ultra-miniature endoscope with a diameter of less than 1mm. To accomplish this innovation, the scope is equipped with a unique optical system comprised of a micro-lens and a diffraction grating at the tip of the optical fiber.

Through commercialization of a high resolution endoscope that is significantly thinner than conventional devices and which is robust enough to maintain its integrity within the body, Canon aims to facilitate early treatment and new diagnostic applications. This technology will enable physicians to observe inside joints or sinuses, which were previously inaccessible in real time.

Needle-Guiding Systems

Image-Guided Navigation Software and Robot for Accurate Needle Insertion

Canon is also developing a system to ensure the precise insertion of needles into organs. Normally, a doctor viewing CT or MRI images outside of the operating room will confirm the location of a cancer site or the target position of a needle.

With this system, however, the physician specifies the target position for the needle to be inserted into the abdominal or chest cavity using image-guided navigation software, based on which the device will set the angle of insertion accordingly and guide the physician to ensure that the needle correctly reaches the targeted organ location.

In addition to this proof-of-concept system, Canon is also developing motors and sensors that operate in an MRI environment. This system will allow doctors to more efficiently and with greater accuracy perform such procedures as biopsies or ablation (treatments using either high or low temperature to destroy cancer cells) which, greatly rely on the memory of the physician.

Glossary

* Novallele Genotyping Assays

Novallele genotyping assays enable the detection of specific genetic variations. These variations include both single nucleotide changes, or insertions and deletions of larger segments of DNA.

Note: For research use only. Not for use in diagnostic procedures.

Genetic testing products under development

Nanoimprint Lithography

Exceeding

the Limits of Miniaturization

As we approach the perceived limits of miniaturization, Canon's nanoimprint lithography technology is about to trigger a revolution in semiconductor manufacturing.

Nanoimprint Lithography: The Ultimate Microfabrication Technology

The evolution of semiconductor chips directly correlates to the history of circuit miniaturization. The key to this miniaturization is the shortening of light-source wavelengths and advances in lithography technologies. In the early 1990s, Canon introduced its i-line 365 nm wavelength (nm = nanometer, one billionth of a meter) steppers, making 350 nm resolution possible for a variety of imaging applications. In the late 2000s, new shorter-wavelength light sources were developed, leading to the creation of an argon fluoride (ArF) immersion lithography system capable of 38 nm-resolution patterning. At the time, it was believed that miniaturization had reached its technological limit.

As an alternative to shorter wavelengths, Canon is currently establishing a new approach to circuit miniaturization. That approach is nanoimprint lithography (NIL), which exceeds conventional lithographic limitations and does so at lower cost. Capable of achieving line widths of a mere 15 nm, and maybe even smaller, NIL is poised to revolutionize the semiconductor industry.

Overcoming Numerous Technological Challenges

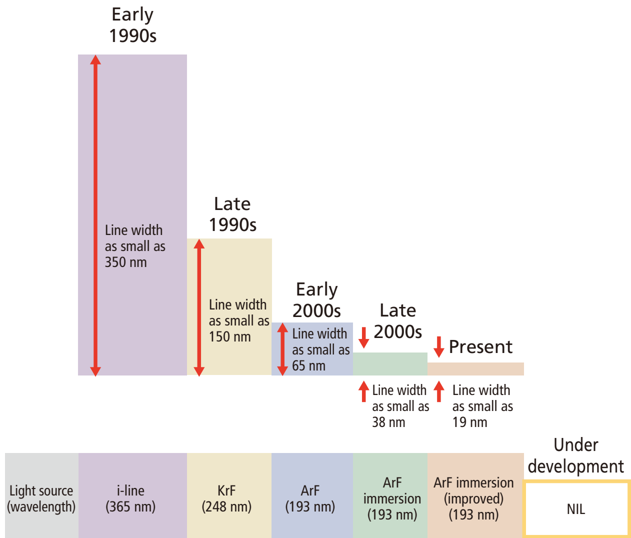
Unlike conventional lithography technology that uses light to expose circuit patterns, nanoimprint lithography fabricates nanometer-scale patterns by transferring the nano-pattern mask (mold) onto the coated resin on the wafer surface to form circuits. Because the process involves no optical system, it enables the faithful reproduction of the mask's minute circuit patterns on the surface of the wafer. However, because the circuit patterns are formed using direct transfer, the process requires nanometer-level control technologies for accurately positioning the mask and wafer, eliminating particle contaminants and other operations. Through the comprehensive development of hardware, software and materials technologies, along with environmental control technologies to keep microscopic particles in check, Canon successfully overcame these numerous obstacles.

One of the technologies Canon developed for nanoimprint lithography controls the amount and positioning of the resin that is applied to the wafer surface. This technology precisely controls how much and where the resin is applied to prevent it from being squeezed out when the mask is pressed into the resin, while also ensuring the formation of a resin layer with a uniform thickness. Likewise, when the mask is removed from the wafer, their relative positions must be optimally controlled to prevent the deformation of the convex circuit patterns formed in the resin.

Generating Synergies from Different Cultures

With the aim of mass producing nanoimprint lithography systems, Canon is collaborating with U.S.-based Canon Nanotechnologies, Inc. (CNT), which boasts some of the world's most advanced and unique technologies for microfabrication devices in the field of nanoimprint lithography. In addition to lithography system control and measuring technologies, the service and support know-how that the company has cultivated to date are essential to Canon's development of semiconductor lithography systems. By merging these with CNT's cutting-edge nanoimprint lithography technologies, Canon aims to break through the current physical limits of miniaturization.

The History of Semiconductor Miniaturization

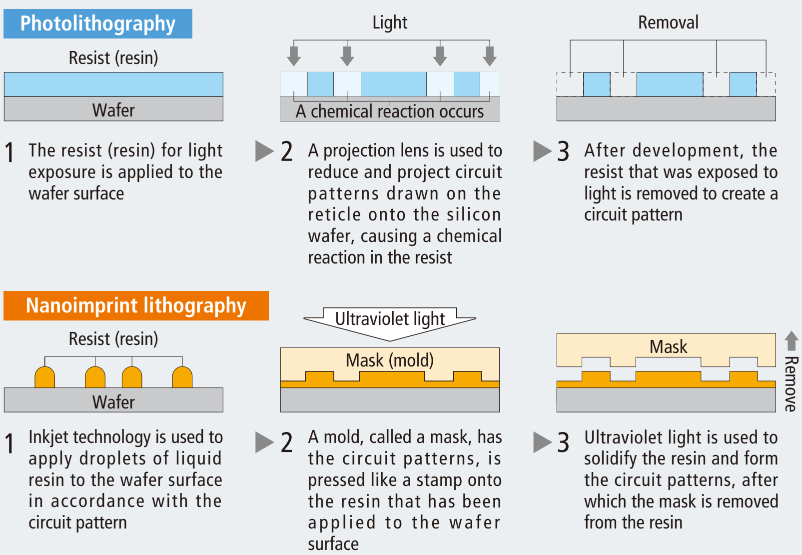


While line widths have halved roughly every five years, progress has stalled since the late 2000s

How Canon Nanoimprint Lithography Works

While photolithography has contributed to reducing the cost of semiconductor chips, as line widths grew narrower, it became increasingly difficult to achieve sharper circuit pattern definition. Consequently, further miniaturization required various workarounds that resulted in ever-larger and more expensive lithography systems.

In contrast, nanoimprint lithography does not require shorter-wavelength light sources, instead using the simple approach of physically pressing patterns on a mask onto the resin. As such, it enables the creation of lithography systems that are relatively compact in size and have the potential to significantly lower costs. Also, because this approach produces extremely sharp circuit patterns, it is expected to contribute to lower chip-defect rates.

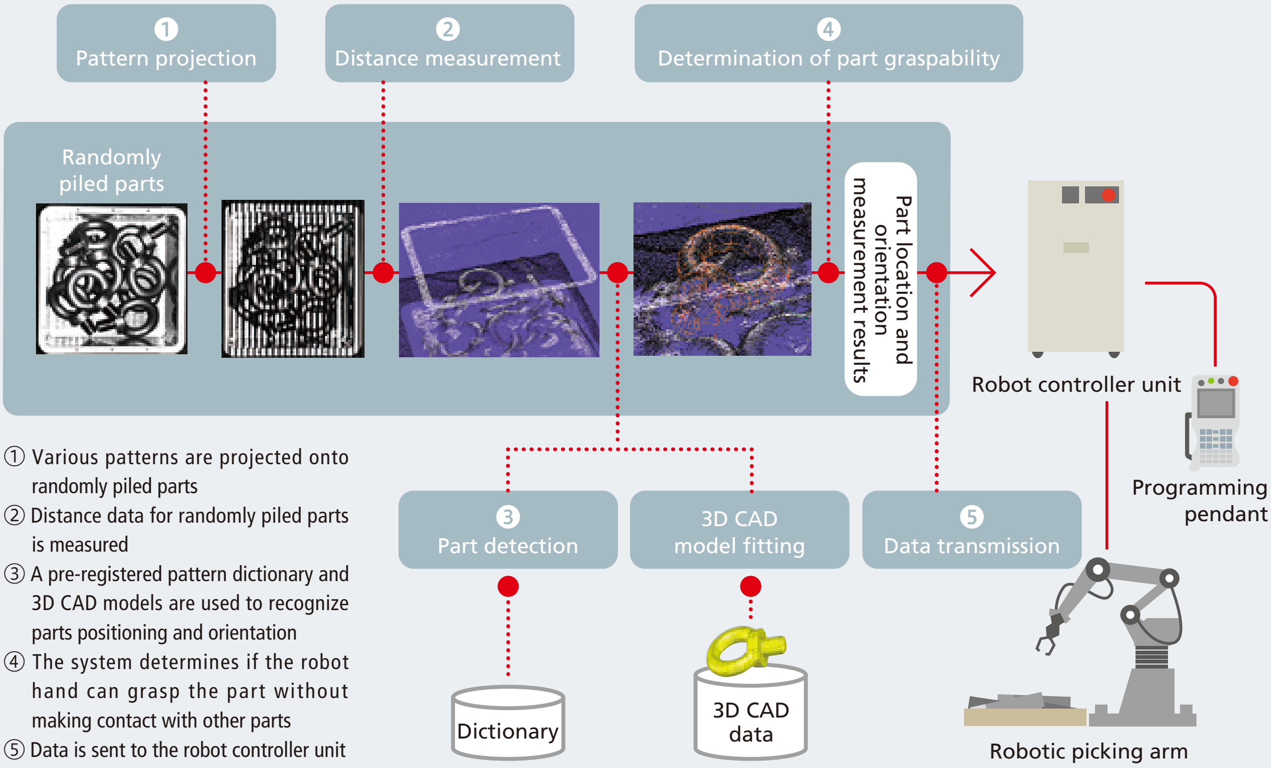


3D Machine Vision

Solving
Manufacturing Issues

Highly accurate identification of the location and orientation of randomly piled parts in three dimensions facilitates the automation and acceleration of production lines for parts feeding.

3D Machine Vision System Workflow



① Various patterns are projected onto randomly piled parts
② Distance data for randomly piled parts is measured
③ A pre-registered pattern dictionary and 3D CAD models are used to recognize parts positioning and orientation
④ The system determines if the robot hand can grasp the part without making contact with other parts
⑤ Data is sent to the robot controller unit

Using 3D Machine Vision to Solve Issues on the Production Floor

While robots play an essential role in the manufacturing industry, there are some tasks for which they are ill-equipped. One such task is the selection and pickup of individual parts from randomly piled parts in a box or on a pallet.

This meant that workers would have to position each part at a designated spot for pickup by robot, creating a bottleneck amid efforts to streamline and automate production lines.

Canon's 3D machine vision system solves this issue. Machine vision refers to the use of industrial image sensors. The most common form of machine vision currently in use is 2D machine vision, which has difficulty identifying the positioning and orientation of randomly piled parts. As a solution, Canon developed the RV1100, a machine vision system capable of high-speed, high-accuracy three-dimensional recognition of objects. This system enables the automation of parts supply on production lines, a task that conventionally has had to be performed manually, and opens up new possibilities on the front lines of manufacturing. In July 2015, Canon expanded its machine vision product lineup with the launch of the RV500 and RV300, both of which make possible pickup of smaller parts. Canon's machine vision lineup is therefore well suited to a wide range of production applications, including those of the electronics industry, which requires the handling of small parts and components.

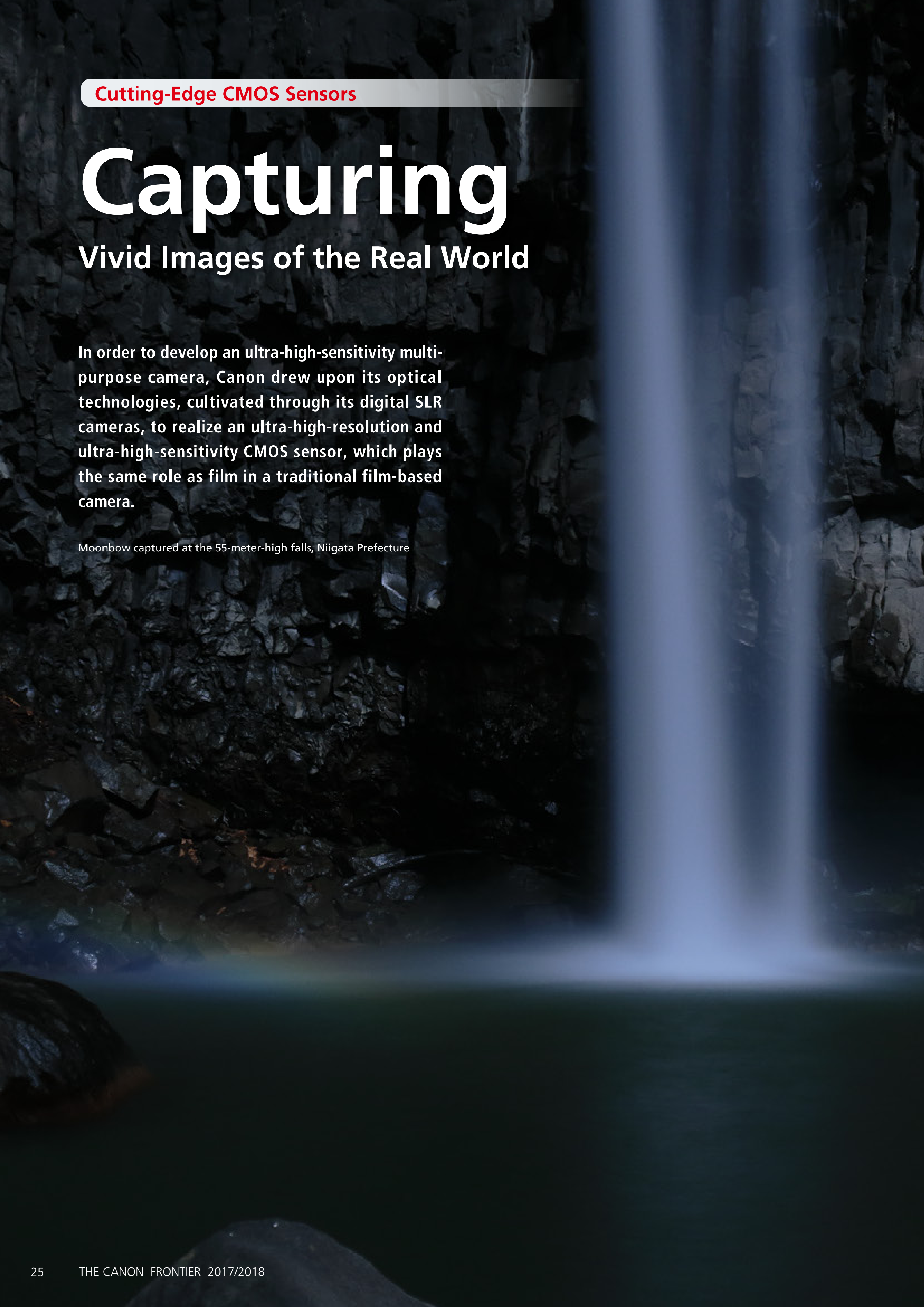
Easy Installation with Integrated Projector and Imaging Sensor

Canon's 3D machine vision systems project recognition patterns onto randomly piled parts and analyzes the projected images. Based on the analysis of the differences between images of the parts and the multiple projected patterns, the systems are able to recognize targeted objects in three dimensions. With conventional 3D machine vision systems, the pattern projector and the imaging sensor are separate, which requires careful calibrations and makes the systems difficult to install. By comparison, Canon's 3D machine vision system is easy to install, without the need for difficult calibrations, as it incorporates both the pattern projector and imaging sensor in a single unit. This lightweight, compact design also enables easy installation when changes are made in a production line or the line is relocated. Additionally, the system features a dust- and water-resistant body design for maintenance-free operation.

Reaching Higher Speeds and Higher Precision in Parts Recognition

Canon's 3D machine vision system delivers unrivaled recognition precision. Users can easily register parts with curved surfaces, parts with few distinguishing features and even parts with more complex shapes simply by inputting the CAD data and capturing images of the randomly piled parts. Also, a new approach that matches CAD data with distance measurement data and gray-scale images allows the system to recognize a wide variety of parts with high precision. Canon has received orders from manufacturers across a range of industries, including automotive, electronics, metal equipment, resin and chemical industries. The company also aims to expand its business in the future through the introduction of systems for assembly processes and the automation of defect inspections.

Scan to access a special video and learn more about 3D machine vision



Cutting-Edge CMOS Sensors

Capturing

Vivid Images of the Real World

In order to develop an ultra-high-sensitivity multi-purpose camera, Canon drew upon its optical technologies, cultivated through its digital SLR cameras, to realize an ultra-high-resolution and ultra-high-sensitivity CMOS sensor, which plays the same role as film in a traditional film-based camera.

Moonbow captured at the 55-meter-high falls, Niigata Prefecture

Ultra-High-Sensitivity 35 mm Full-Frame CMOS Sensor

A CMOS Sensor Capable of Clear Color-Image Capture by the Light of a Crescent Moon

From surveillance to observing natural phenomena, there is a growing need to capture video in complete darkness. Canon has developed an ultra-high-sensitivity sensor capable of Full HD video capture in color with reduced noise, even with minimal subject illumination—conditions under which subjects would be difficult to discern with the naked eye.

One way to better capture clear video images in low light environments is to enlarge the pixels on the CMOS sensor, increasing the amount of light each pixel is capable of receiving. In 2013, Canon announced the development of a prototype camera equipped with a 35 mm full-frame CMOS sensor for video capture. The sensor featured large-scale pixels measuring 19 μm (μm = micron, one millionth of a meter) square. Compared with the CMOS sensor incorporated into Canon's top-of-the-line EOS-1D X digital SLR camera, the pixels on this CMOS sensor have more than 7.5 times the surface area, enabling them to receive greater amounts of light.

In addition to enabling video capture in a dark room with no more illumination than that provided by burning incense sticks (approximately 0.05–0.01 lux), the ultra-high sensitivity 35mm full-frame CMOS sensor also succeeded in capturing nighttime video (in an exceptionally dark shooting environment of less than 0.01 lux) of the Yaeyama-hime fireflies that inhabit Japan's Ishigaki Island.

Canon further refined the performance of the sensor and incorporated it into the company's first ultra-high-sensitivity multipurpose camera, the ME20F-SH, which was launched in 2015 and is capable of capturing color video with a minimum subject illumination of less than 0.0005 lux, equivalent to an ISO sensitivity of 4 million (at maximum 75 dB gain).

In 2016 this multipurpose camera was used to successfully shoot video of a moonbow, a natural phenomenon rarely seen in Japan, using only the light of the moon.

Multipurpose cameras capable of operating in almost total darkness enable image capture in locations that are otherwise difficult to access. In addition to applications in disaster prevention and crime prevention, other possible uses include measuring instruments and industrial machinery, as well as shooting video of wild animals in their natural habitats.

ME20F-SH

Comparison of images captured under identical conditions

Conventional professional-use video

Moonbow shot with the ME20F-SH, Canon's ultra-high sensitivity multi-purpose camera

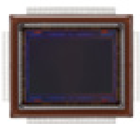
Ultra-High-Resolution 250 Megapixel CMOS Sensor

Five Years since 120 Megapixels Going for the World's Highest Pixel Count*

Canon was quick to launch R&D efforts on CMOS sensors as far back as the 1990s. In 2010, the company produced a CMOS sensor with 120 megapixels, achieving a level of resolution equivalent to that of the human eye, a feat that garnered considerable attention from the industry. In 2015, Canon successfully developed an APS-H-size CMOS sensor with approximately 250 megapixels (19580 x 12600 pixels), the world's highest pixel count for its size. This ultra-high-pixel-count CMOS sensor achieves a level of resolution that is approximately 125 times that of Full HD (1920 x 1080 pixels) video and approximately 30 times that of 4K (3840 x 2160 pixels) video.

Despite the compact pixel dimensions, sensitivity was maintained by creating a structure that maximizes the amount of light captured. Additionally, though increases in pixel count results in increased signal volume, which can cause signal delays and timing discrepancies, an ultra-high signal readout speed of 1.25 billion pixels per second was achieved through circuit miniaturization and enhanced signal-processing technology. Accordingly, the sensor is capable of capturing ultra-high-pixel-count video at a speed of five frames per second.

* As of September 7, 2015. Based on a Canon survey



CMOS sensor with approximately 250 megapixels

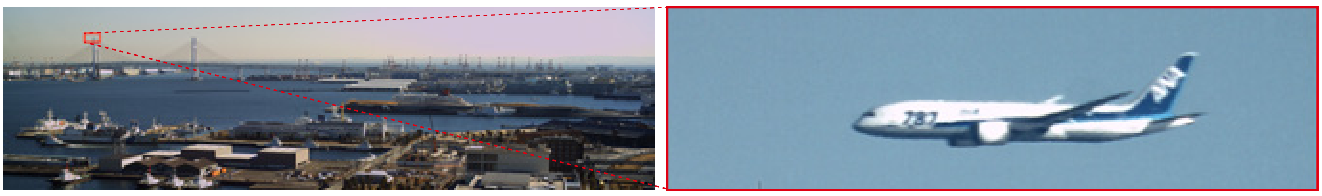
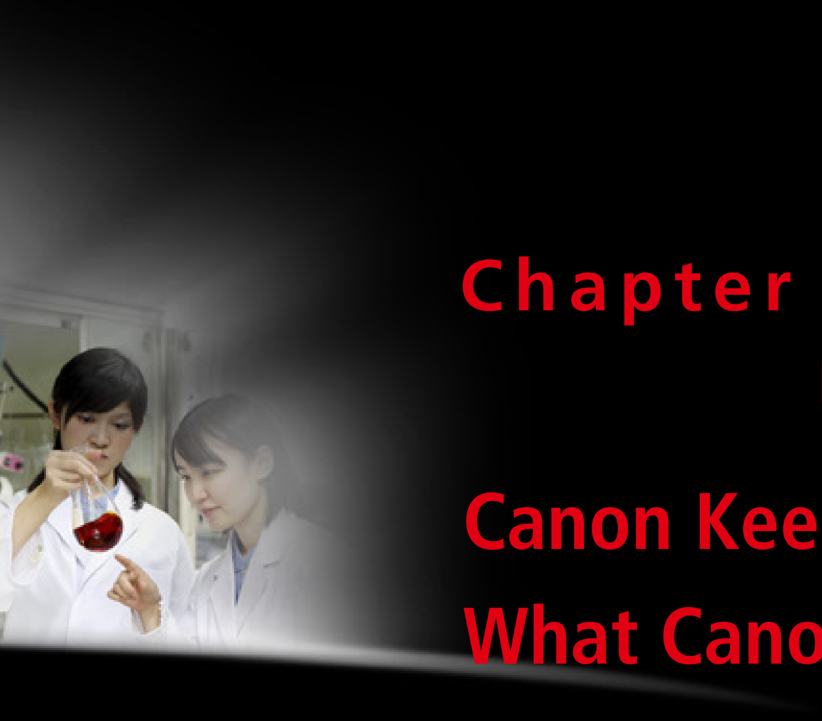


Image captured with a prototype camera equipped with an EF 800mm telephoto lens using digital zoom. The image was digitally enlarged and additional image processing was applied.
The resulting image enables the identification of lettering on the fuselage of an airplane 18 km away, which would otherwise be difficult for the human eye to perceive.

New Product CMOS Sensor with Global Shutter

Canon has announced its global shutter-equipped CMOS sensor—which captures image data all at once—for industry, instrumentation and film production. By exposing all of the sensor's pixels at the same time, this new CMOS sensor eliminates the "rolling shutter" effect, a distortion caused by line-by-line capture of fast-moving subjects while improving both sensitivity and noise reduction.

Scan to access a special video and learn more about Canon's cutting-edge CMOS sensors.



Chapter 2

Canon Keeps Doing What Canon Does Best

The vibrant brand image of
Canon draws upon its tremendous technical strength
in developing products, from highly original product design to ink materials.
In this section we introduce the diligent efforts being made at Canon
that will enable our global brand to develop even further.

Canon Design

Design

that Enhances Brand Value

Corporate image is not limited to products and services; the impressions made by advertising and publicity also play a role in its formation. Through the proposal of new value and the creation of high-quality designs in harmony with all corporate initiatives through which Canon engages with its customers, Canon Design contributes to boosting the company's brand value.

Design for Product Quality

Canon offers a diverse product portfolio that includes not only a broad lineup of cameras, video camcorders and inkjet printers for both professional and general users, but also a wide range of office-use products, such as copying machines and projectors, as well as industrial products like medical equipment and semiconductor lithography systems. The company also offers web services that provide users with additional ways to enjoy photography.

Aiming to deliver optimal ease of use across a range of usage scenarios, Canon surveys and analyzes customer usage environments, needs and preferences, while focusing on appealing designs that enhance user convenience.

Through a coordinated effort among the divisions responsible for product design, user interface design, usability design and visual design, Canon meticulously refines each and every one of its products.

Design in Corporate Activities

Aside from products, design also plays an essential role in such areas as Canon's environmental initiatives, CSR activities and recruiting efforts. The messages that the company sends to its customers, as well as its employees, must be informative and easy to understand—yet another indispensable role of design.

Design for Tomorrow

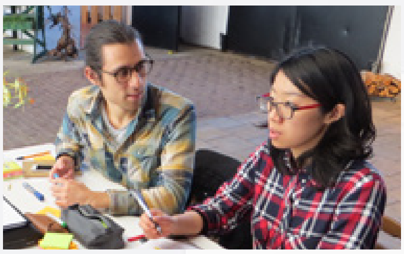
What will our world look like five or ten years from now? What changes can we expect to see in the workplace and in our lifestyles? And how will design influence these developments? With an eye to the future, Canon Design attempts to visualize what lies ahead and create new proposals, another important job that is essential for the Canon of tomorrow.

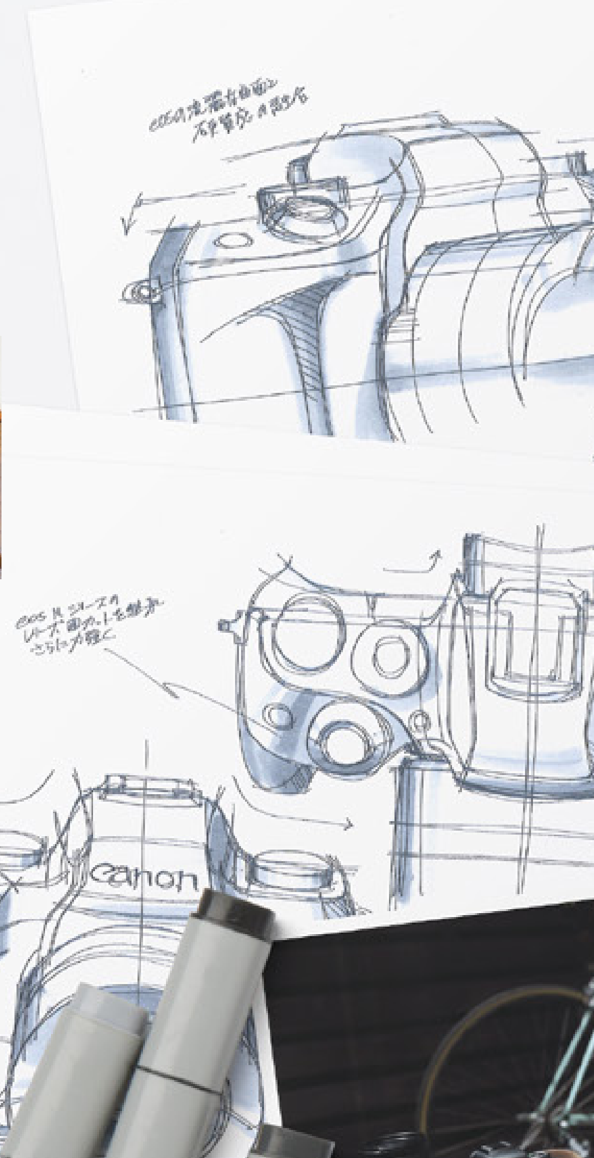
Study-Abroad Program for Engineers

As part of the company's R&D globalization efforts, Canon offers a study-abroad program for its engineers. The Canon Design Center also sends company designers overseas on this program. As a result, overseas-study experiences are being put to substantial use in the design development process.

Design Awards

The Canon Design Center proactively participates in design competitions both in Japan and overseas and has been recognized with Good Design Awards, iF Design Awards and numerous other awards. The opportunity to have designs evaluated by knowledgeable outside authorities not only enhances the quality of Canon designs, but also leads to the growth of the company's designers.






EOS M5
DIGIC 7
Canon

Intellectual Property Activities

Protecting Our Intellectual Property

Common refrains heard within Canon's research and development division include, "Read patent bulletins rather than research literature," and "Create draft patents rather than reports." It is in Canon's DNA to avoid patents held by other companies, instead developing original technology and protecting it through patents.

Canon, the Top Japanese Company Among U.S. Patent Recipients for 12 Consecutive Years Through Proactive IP Activities

Canon believes that acquiring patent rights for its proprietary technologies is an essential and important aspect of expanding operations globally.

Every year, Canon engineers submit more than 10,000 ideas with patent applications filed by country and region. In the United States, Canon has been the top-ranked patent recipient among Japanese companies for 12 straight years.

There are two aspects to Canon's intellectual property strategy. The first is defensive—to protect Canon's proprietary core technologies from being infringed upon by others. The second is offensive—to create advantages for Canon's operations by acquiring multiple patents that other companies, not just Canon, need to use, and then negotiating licenses for their use. Through both defensive and offensive intellectual property management, Canon strengthens its product development capabilities.

Number of U.S. Registered Patents

Year	Rank overall	Rank among Japanese companies	No. of patents
2016	3rd	1st	3,665*
2015	3rd	1st	4,134
2014	3rd	1st	4,048
2013	3rd	1st	3,820
2012	3rd	1st	3,173
2011	3rd	1st	2,818
2010	4th	1st	2,551
2009	4th	1st	2,200
2008	3rd	1st	2,107
2007	3rd	1st	1,983
2006	3rd	1st	2,366
2005	2nd	1st	1,829

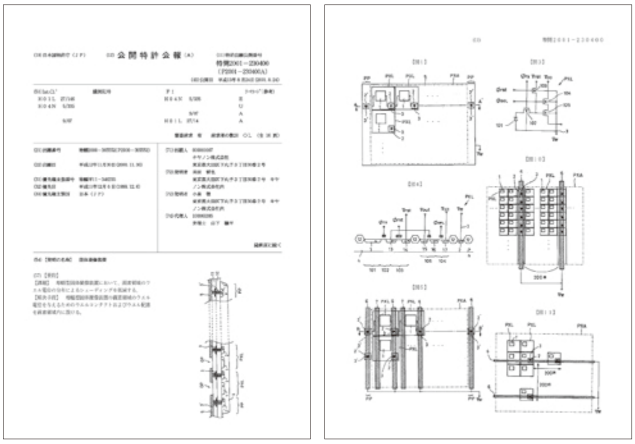
Figures tabulated by Canon based on annual information issued by the U.S. Department of Commerce
* Figure for 2016 taken from IFI Claims Patent Services

Patent Strategy to Tackle Xerox's Monopoly

Canon's emphasis on intellectual property rights dates back to the 1960s, when the company entered the copying machine market.

In order to break through the airtight patent wall that U.S.-based Xerox had erected for its copying machines, Canon invented the NP method, an all-new electrophotographic technology that did not infringe on Xerox's patents. By acquiring the patent rights to this technology, the company was able to protect the proprietary technology that made it different from other companies. Additionally, by acquiring peripheral technologies, Canon put itself in the position to negotiate license agreements for technologies needed by other companies. This experience created the foundation for Canon's intellectual property strategy and has been passed down through the generations as part of Canon's corporate DNA.

Published patent application (excerpt)



Engineers Work Closely with Patent Engineers to Cultivate Ideas

One major characteristic of Canon's intellectual property strategy is the active exchange of communication between engineers and patent engineers, who are in charge of intellectual property. Some 300 patent engineers at Canon operation sites throughout Japan examine new ideas and the research results of engineers from various angles, searching for ways to maximize the number of inventions that can be generated.

Basic Policy of Canon Intellectual Property Activities

◎ **Intellectual property activities are vital to support business operations**

◎ **The fruits of R&D activities are products and intellectual property rights**

◎ **Other parties' intellectual property rights should be respected and attended properly**

Collaborations with Global Companies

In this day and age, where cars are equipped with multiple cameras and some 100,000 patents exist for smartphones, it has become increasingly difficult for Canon to protect its technologies on its own.

In a move to assert the company's legitimacy and circumvent international patent disputes, Canon signed a cross-licensing agreement* with Microsoft in July 2014. Furthermore, with the aim of reducing patent litigation risks involving Patent Assertion Entities (companies specializing in filing patent-related lawsuits aimed at collecting licensing fees), six companies, including Canon and Google, established the License on Transfer (LOT) Network. As of January 2017, 107 companies have joined as members. In this way, Canon is working to coordinate with other companies to strengthen its competitive edge internationally through intellectual property.

* In a cross-licensing agreement, patent-right holders (companies, etc.) grant a license to each other permitting the use of a patent or patents held by the other party.

History of Awards for Canon Inventions

Several Canon inventions have often been awarded Japan's National Commendation for Invention (sponsored by the Japan Institute of Invention and Innovation), presented in recognition of inventions of great merit in Japan. Through the establishment of an internal Commendation for Invention system, Canon gives special recognition to the efforts of engineers and other meritorious individuals for their outstanding inventions.

Canon's Recognition by Japan's National Commendation for Invention and Internal Invention Awards over the Past 20 Years

Name of Invention	The Special Prize, National Commendation for Invention, Japan Institute of Invention and Innovation		Internal Invention Awards	
	Year	Name of Award/Prize	Year	Name of Award/Prize
Invention of shading-reduction technology for CMOS sensors	2015	The Prize of The Chairman of Japan Business Federation	2005	President's Incentive Award
Design of a compact, lightweight digital cinema camera with outstanding mobility	2014	The Prime Minister Prize	2013	President's Award for IP Achievement
Invention of a printer using intermediate transfer member, without a cleaning mechanism	2013	The Prize of The Minister of Education, Culture, Sports, Science and Technology	2004	President's Award for IP Achievement
Box-shaped inkjet printer	2006	The Asahi Shimbun Prize	2005	President's Award for Excellence
Large-area sensor for real-time digital radiography system	2005	The Imperial Invention Prize	2001	President's Award for Excellence
Invention for a small-size optical system capable of high-speed zoom	2003	The Asahi Shimbun Prize	2004	President's Award for Excellence
Slim flatbed scanner design	2002	The Prize of The Chairman of Hatsumei Kyokai (JIII)	2001	President's Award for IP Achievement
Ozone-less charging method	1999	The Prize of Commissioner of the Japan Patent Office	1991	President's Award for Excellence
Invention of active type distance measuring device	1997	The Asahi Shimbun Prize	1996	President's Award for IP Achievement

Material Research

Supporting
Product Originality

Foundational material technologies, such as those for colorants, toners and optical glass, are essential for boosting product competitiveness. Capitalizing on the many decades Canon has invested in researching such materials, the company has compiled its expertise and know-how to establish the Canon Material Bank, a valuable resource for use throughout the company.

Protective eyewear removed for photo only

High-Color-Performance Xanthene-Based Dyes

A Vivid Red that Never Fades

In the past, printer manufacturers did not develop their own colorants in-house, but rather would procure common dyes from other companies, which made it difficult for them to differentiate their colors from those of competing manufacturers. Canon, however, focused its development efforts on xanthene-based dyes, which boast superior coloration properties, to create a dye capable of producing high-visibility reds. Although finding a practical application for xanthene dyes was considered difficult due to challenges regarding robustness (light colorfastness), the company's research efforts paid off with the successful development of a new magenta dye that enables the printing of reds that are both robust and vivid.

Employing Proprietary Molecular Design in Search of Improved Robustness

Canon began developing new dyes in the 1980s and has now amassed more than 10,000 types of dyes in its Canon Material Bank. The bank represents a database of a diverse variety of technological know-how that, in addition to information on synthetic and physical properties, includes data on the mechanisms behind the breakdown of dyes when exposed to such stimuli as external light and ozone gas. During the development of the dyes, Canon conducted repeated simulations, molecular designs, synthesis, evaluations and analyses, arranging specific substituents in optimal locations to achieve both desired coloration performance and robustness. The result was the birth of new dyes.

From the Lab to Mass Production

The next challenge that needed to be addressed following the creation of the xanthene-based dyes in the lab was mass production. Unlike the compact 300-milliliter reaction vessels used in laboratories, those used in mass production, with capacities exceeding 1 ton, are of an altogether different scale. With inkjet printers in particular, because ink ejection must be controlled at the picoliter level, even the slightest amount of impurities during synthesis could cause the ink nozzles in the printhead to clog. Accordingly, the company's element development division and business group conducted joint research aimed at reducing impurities to less than one part per million. The collaborative effort paved the way for commercialization by ensuring consistent ink quality, even during mass production.

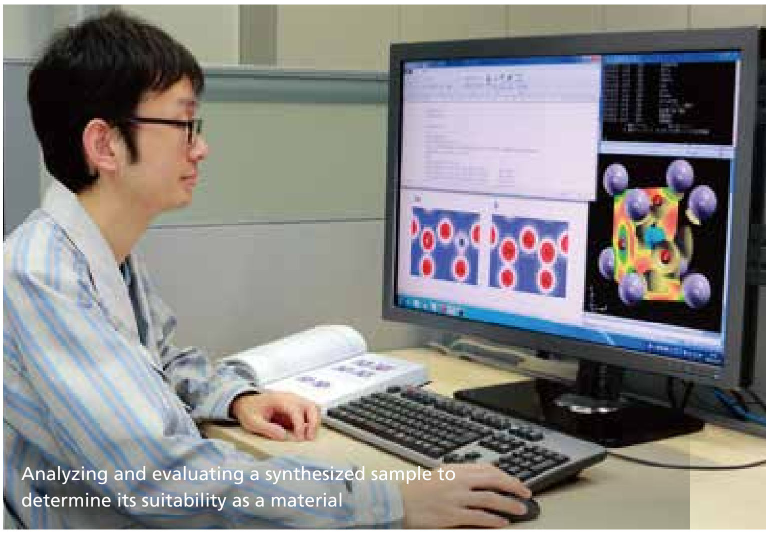
Photo printed with ink using new xanthene-based dyes

Lead-Free Piezoelectrics

Piezoelectrics: A Valuable Material with Significant Environmental Impact

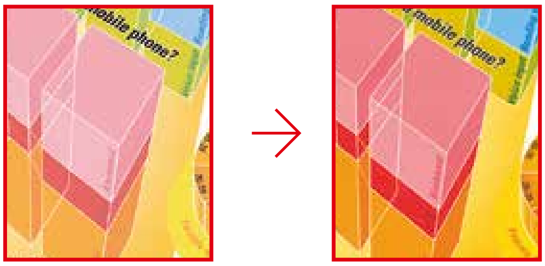
Piezoelectric materials, which are essential for motors and sensors, have the ability to transform electrical energy into mechanical energy. Most piezoelectric materials, however, contain lead as a principal component. Lead has a negative impact on the environment, which has led to the call for lead-free piezoelectric materials within the industry. In addition to lenses and solder, Canon is trying to eliminate lead from piezoelectric materials, developing new lead-free materials toward the goal to launch new products which include these materials.

Preparing samples of lead-free piezoelectrics for analysis by sintering combined raw particles



Analyzing and evaluating a synthesized sample to determine its suitability as a material

Making vivid printing possible through improved color performance



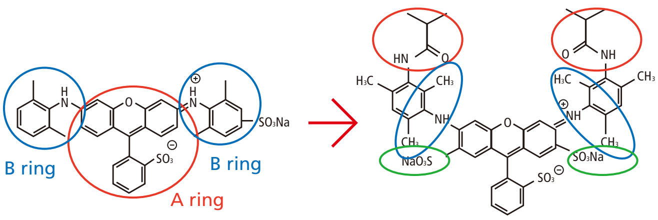
Earlier product

Printed using new BCI-351 xanthene-based dyes

Compared with earlier Canon products, BCI-351 inkjet printer inks realize improved magenta color performance

Molecular structure of newly synthesized new xanthene-based dyes

[Base dye] [New xanthene-based dye]



Both high robustness and color performance are achieved through the arrangement of substituents in optimal locations

Participation in a National Project in Japan

From 2007 to 2012, Canon participated in a national project called the Element Strategy Initiative, launched by Japan's Ministry of Education, Culture, Sports, Science and Technology. The goal of this project was to create new high-functional materials by shedding light on the manifestation mechanisms of functions through research into the roles and properties of elements that make up substances. Through this project, Canon aimed to propose new lead-free piezoelectric materials that possess piezoelectric properties exceeding those of widely used lead-based piezoelectric materials. These efforts became the basis for research and development being carried out today.

Tsuzuri Project

Bringing

the Art of Antiquity into the Future

The Tsuzuri Project is an initiative that combines the latest digital technologies with traditional artisanal work to replicate precious works of Japanese art that are rarely seen by the public. The initiative promotes cultural appreciation by bringing artistic works of antiquity into the future.

High-resolution facsimile of “Tigers in Bamboo Grove” by Kano Sanraku/Sansetsu from sliding door at Tenkyuin Temple

Production Process 1 — Input

Segmented capturing of high-resolution data of a large painting on a sliding door

Production Process 2 — Color Matching

Output on-site and quickly color matched with the original

Production Process 3 — Output

World-class printing technology employed to reproduce fine textures

Preserving Original Cultural Assets While Making Facsimiles Available to the Public

Japan has numerous valuable cultural assets in the form of paintings on folding screens and sliding doors made of paper using India ink and natural mineral pigments. These works of art are fragile and easily damaged. Temples throughout Japan are struggling to preserve their aged and fragile relics while showing them to a constant stream of eager visitors.

The Tsuzuri Project was launched by Canon and the Kyoto Culture Association (NPO) in 2007. Through the initiative, high-resolution facsimiles of these cultural assets are created, which allows the original cultural assets to be preserved in a controlled environment while the near-perfect facsimiles can be widely exhibited to the public.

A Canon EOS 5D Mark III digital SLR camera is used to photograph the works of art. The image data that is captured then undergoes Canon's proprietary color correction and the processed image is then printed in full scale using a Canon imagePROGRAF large-format inkjet printer. Master Kyoto artisans add various finishing touches as necessary, such as applying gold leaf and mounting the work. The result is a high-resolution, near-perfect replica of the original work.

To date, high-resolution facsimiles of some 34 works have been created (as of April 2016). These include many national treasures, such as "The Wind and Thunder Gods" by Tawaraya Sotatsu, "Pine Trees" by Hasegawa Tohaku, and "The Three Portraits of the Jingoji Temple", attributed to Fujiwara no Takanobu.

Many of the Tsuzuri Project's facsimiles are donated to municipal organizations, museums or the original cultural assets' past or present owners, and are widely exhibited to the general public. Enabling more and more people to experience these precious cultural assets from ancient Japan, the Tsuzuri Project is proving instrumental in the creation of opportunities for the public to rediscover Japanese culture.

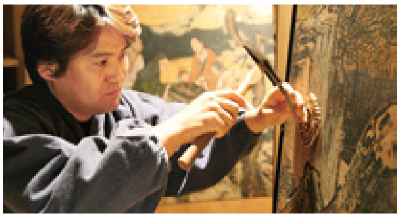
Some reproductions are also used in educational settings, such as classrooms and workshops involving Japanese history, culture or art. The project's use of cutting-edge technology has been praised for going above and beyond conventional digital archiving.

Production Process 4 | Gold Leaf, Gold Paint and Mica

Colors degraded over time are reproduced through traditional craft techniques

Production Process 5 | Mounting

Kyoto master craftsman uses time-honored mounting technique



Scan to access a special video and learn more about the Tsuzuri Project.

Exploring
the Origins of the Universe

Astronomy is a field that requires advanced optical and imaging technologies, the core strength of Canon. In recent years, Canon has been involved in the Thirty Meter Telescope (TMT) project to build an extremely large 30-meter-diameter telescope in Hawaii. Canon has also been working independently to develop an immersion diffraction element that will significantly reduce the size of infrared spectrometers.

TMT

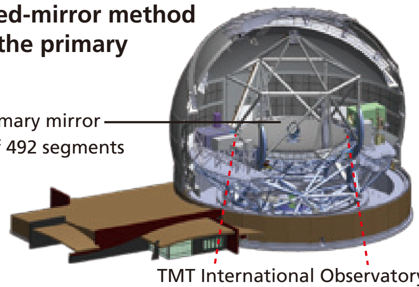
Important Work on a International Collaborative Project

The TMT is a five-nation international collaborative project supported by Japan, the United States, Canada, China and India to construct a huge, 30-meter-diameter telescope. Canon's proven track record in the development and manufacture of optics for the Subaru Telescope earned the company a role in manufacturing the mirror segments for the TMT.

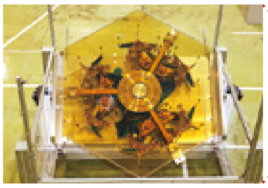
The TMT's 30-meter-diameter primary mirror will comprise an array of 492 segments (574 when including replacement segments), the fabrication of which is being carried out in Japan, the United States, China and India. Japan is responsible for the production of approximately 30% of the mirror segments. Plans call for Canon to handle such work as grinding and polishing the mirror surfaces, outer-shape cutting and support-assembly mounting. In 2014, the company commenced mass production aspherical grinding processes.

The hexagonal segments, made of ultra-low-expansion glass, each measure 1.44 meters diagonally with a thickness of 45 millimeters. The maximum asphericity is 0.2 millimeters, requiring a level of precision of less than 2 microns peak-to-valley. Canon's proprietary contact-type free-form measurement machine (A-Ruler) enables the confirmation of polishing accuracy in the effort to achieve precision polishing.

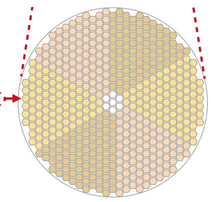
The segmented-mirror method employed in the primary mirror



TMT International Observatory



Prototype fabricated by Canon of a segment from the primary mirror



Configuration of the 492-segment primary mirror

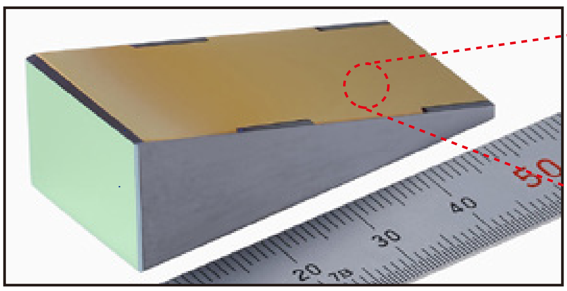
Photo illustration of the completed TMT (courtesy of the National Astronomical Observatory of Japan, in cooperation with Mitsubishi Electric Corporation)

Infrared Immersion Gratings

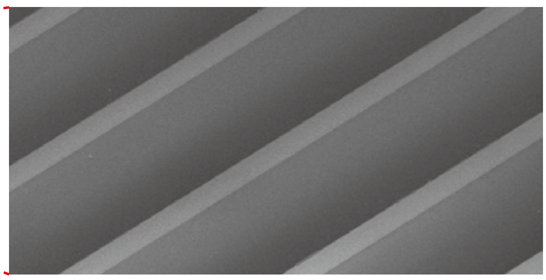
Higher-Performance Infrared Spectrometers Could Shed Light on History of the Universe

To retrieve information contained within light emitted from space, astronomical telescopes and space satellites are equipped with spectroscopes that incrementally separate light by its different frequencies and play a vital role in cosmological observation. The spectroscope contains a reflective element known as an immersion grating and Canon has succeeded in developing three types—made of single-crystal Germanium, Cadmium Zinc Telluride, Indium Phosphide. These three types enable the separation of light into its spectral components, covering nearly all infrared wavelength regions.

Through the use of Indium Phosphide, spectrometers could be reduced to about 1/27th the volume of those equipped with typical reflective elements that cover the same frequencies. Overcoming restrictions on size and weight (which, until now, made it difficult to launch space satellites equipped with high-performance spectrometers) is expected to further expand the possibilities of cosmological observation. This achievement has also fueled expectations of higher levels of performance for existing space telescopes and next-generation ground-based astronomical telescopes.



Indium Phosphide immersion diffraction element
(approx. 50mm (l) x 20mm (w) x 15mm (h))



View of grating surface seen through an electron microscope at 1,000x magnification

Technologies Supporting Canon

Innovative Technologies that Support Lifestyles, Business and Industry

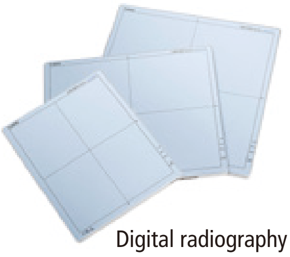
Professional

Professional digital SLR cameras

Ophthalmic equipment

X-ray CT Diagnostic Systems

Diagnostic Ultrasound Systems



Digital radiography

Broadcast equipment

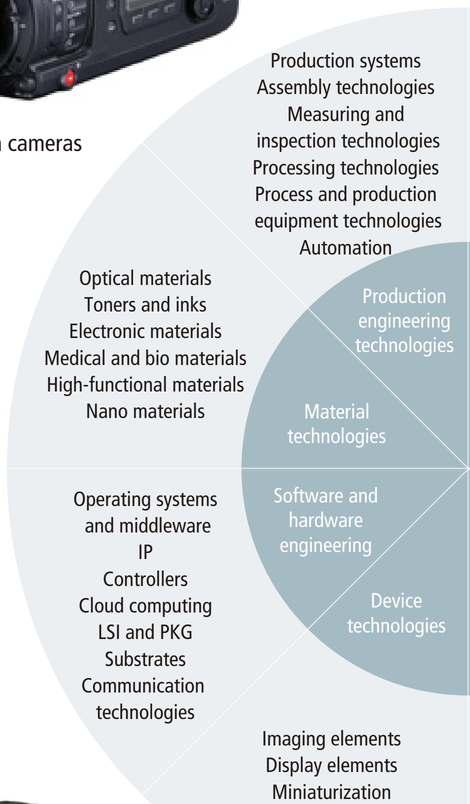
Digital cinema cameras

Professional digital video camcorders

Interchangeable lenses

Professional displays

Professional inkjet printers



Home

Digital compact cameras

Image scanners

Compact photo printers

Connect station

Digital SLR cameras

Inkjet printers

Compact-system cameras

Digital camcorders

Over the course of Canon's more than 70 year history, prioritizing technology has been a part of Canon's corporate DNA and represents the source of Canon's innovative technologies. The unique core technologies that the company has cultivated over the years have led to the creation of eight fields of R&D, which include optical technologies and image communication technologies. The company is engaged in business activities for products and services in four major areas of use: Professional, Home, Office and Industry. With the aim of developing new, one-of-a-kind technologies and products, Canon combines the creativity of its engineers with the company's core technologies to create never-before-seen value.

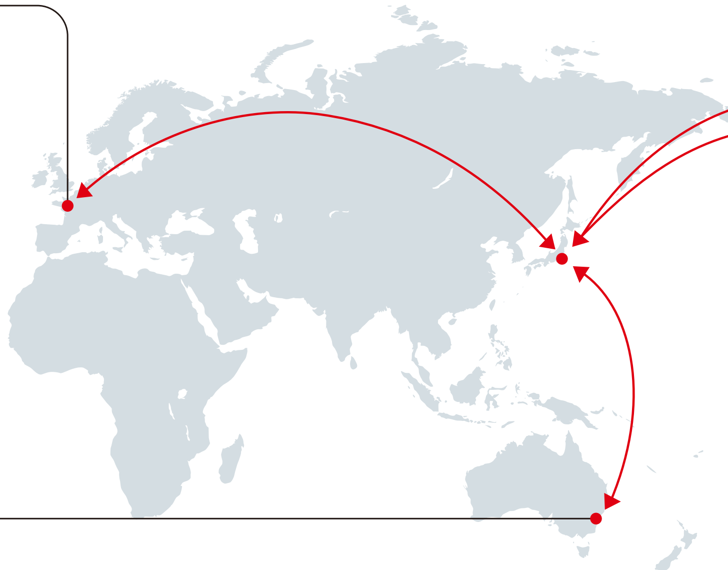
Global R&D

The Canon Group conducts business in more than 220 countries and regions around the world. Today, sales outside of Japan account for more than 80% of Canon's consolidated net sales. To ensure that the research from each of these locations flourishes as businesses, the Canon Group actively collaborates with and engages in exchanges with external research institutes.

Canon Research Centre France S.A.S.

Rennes, France

Research themes: Wireless communications, video transmission



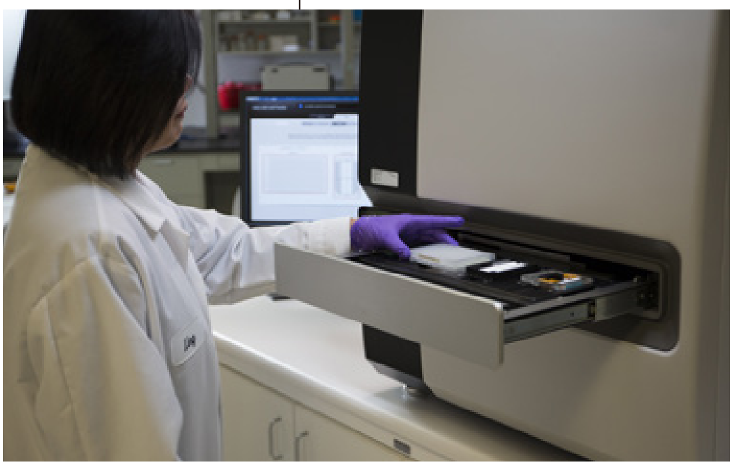
Canon Information Systems Research Australia Pty. Ltd.

Sydney, Australia

Research themes: Image information processing, graphics

Healthcare Optics Research Lab.

(Canon U.S.A.)
Cambridge, Massachusetts
Research themes: Biomedical optical imaging, medical robotics



Canon BioMedical, Inc.

Rockville, Maryland
Research theme: Genetic testing

Three Regional Headquarters Management System: Aiming to Create New Business Sectors

Aiming to expand the company's innovation centers, which are responsible for cultivating business domains, beyond just Japan to include Europe and the United States, Canon is working toward the establishment of a Three Regional Headquarters management system. Canon aims to leverage the characteristics and capabilities unique to these three regions—Japan, the U.S. and Europe—undertaking basic research, applied research and other R&D to create new businesses in the future.

In the United States, Canon's Healthcare Optics Research Lab. (HORL) conducts collaborative research with Harvard-affiliated medical institutions to carry out research and development on optical technologies for the medical field. Additionally, in 2015, Canon U.S.A. established Canon BioMedical to strategically link the fields of life sciences and genetic testing, which employ Canon's existing and new technologies, to develop new businesses.

In Europe, Océ is expanding its collaboration with Canon in Japan and developing technologies involving ink and processes for commercial printing.

Industry-Academia Alliances Pursue Cutting-Edge Optical Technology through Collaborative Research

To strengthen its research and development, Canon is bolstering ties with universities. In 2007, the company jointly established the Center for Optical Research & Education (CORE) in Japan with Utsunomiya University to support optical engineer training and research on state-of-the-art optical technologies.

In 2015, Canon joined the Japanese government's Impulsing PAradigm Change through disruptive Technologies program (ImPACT) to verify the clinical value of photoacoustic equipment developed in collaboration with Kyoto University. Canon will continue to promote joint research with universities and research organizations in Japan and abroad with the aim of developing and commercializing science and technology.

Study-Abroad Program at Overseas Universities Improves Language Skills and Technical Abilities

Since 1984, Canon has offered its engineers a study-abroad program as one of the globalization initiatives of its research and development operations. Engineers who participate in this program study cutting-edge or specialized technologies for two years at a university overseas. The objective of this program is to nurture international engineers, as well as acquire technologies that will play a central role in Canon's future. To date, more than 90 Canon engineers have studied abroad at more than 40 universities, including the Massachusetts Institute of Technology (U.S.A.), Carnegie Mellon University (U.S.A.) and the University of Cambridge (U.K.).

Canon

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